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State of Connecticut

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State Geological and Natural History Survey

VOLUME II

BULLETINS 6-12

HARTFORD
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PRESS OF THE CASE, LOCKWOOD & BRAINARD COMPANY.

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State Geological and Natural History Survey

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SUPERINTENDENT
WILLIAM NORTH RICE

BULLETIN NO. 6

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1906

MANUAL

OF

THE GEOLOGY OF CONNECTICUT

By

WILLIAM NORTH RICE, Ph.D., LL.D.,
Professor of Geology in Wesleyan University

AND

HERBERT ERNEST GREGORY, Ph.D.,
Professor of Geology in Yale University

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1906

Preface.

In the present Bulletin we propose to give, in form and language no more technical than is necessary, an outline of what is known in regard to the geological structure and history of Connecticut.

It is believed that such a work will be useful to various classes of readers. Students of geology in other regions will find here a brief statement of the characteristic features of a small but interesting area. Intelligent citizens of our own State will learn somewhat of the character of the rock formations upon whose surface they live, and of the agencies by which in the course of ages the surface has been molded to its present form and condition. Especially, however, this Bulletin is designed for the use of teachers of science within our own state; and in its preparation we have had particularly in mind that educational aim which is wisely emphasized in the law by which the State Survey was established. From teachers, particularly in the high schools of the state, the question has repeatedly come to us, where can a clear and intelligible account of Connecticut geology be found? To that question no satisfactory answer could be given. While much work has been done in the investigation of Connecticut geology, by private individuals and by officers of the State and National Surveys, the results of that investigation have never been put together in any accessible form. They may be found in part scattered through many volumes of scientific journals and official reports. Much of the older work was published at a time when the language, as well as the thought, of geologists was so different from that of the present time that the writings are not easily intelligible to elementary students at the present day. Many of our teachers do not have access to large libraries, and comparatively few have learned the art of collecting the information which they desire from fragmentary

articles scattered through many volumes. Much of the most recent work on the geology of Connecticut still remains unpublished. It is believed, therefore, that in the work of the teachers of the state this Bulletin will meet a long-felt want.

To geologists it is unnecessary to say, but to the general reader it is important to say emphatically, that this Bulletin does not aim to set forth a complete and final statement of the geology of Connecticut. In spite of all the earnest study that has been given to this field, there are many questions still unanswered; and the knowledge which we possess seems small in comparison with the territory of the unknown. The problems presented by the Triassic are simpler than those presented by the crystalline rocks, and have been much more nearly solved; but, even in regard to the Triassic, important questions still remain without any answer conclusively established or unanimously accepted. Over how wide an area the Triassic sediments extended before the great denudation, and to what extent the western border was formed by faults, are questions in regard to which there is room for difference of opinion. In regard to the dynamics of the tilting and faulting of the Triassic area, any explanation that can be given is only a matter of speculation. In the crystalline rocks the ratio of our knowledge to our ignorance is far smaller than in the Triassic. How much of the crystalline rocks is igneous, and how much is sedimentary in origin; to what extent the foliation represents stratification; what are the stratigraphical relations of the different crystalline formations; in what periods the crystalline rocks of sedimentary origin were deposited, and in what periods they were disturbed and metamorphosed; how many different epochs of disturbance and metamorphism have left their traces upon some of the rocks; all these are questions to which only partial and uncertain answers can be given. Obviously, then, the present paper is in large degree provisional. It is a report of progress; not a final report. It may be hoped that future investigation will correct some of its errors and answer some of its

questions; but, however many interrogation points may be changed to periods in the progress of knowledge, it seems not unlikely that for generations to come the new questions which will be started may be more numerous than the old questions which will be answered. The problem of our crystalline rocks seems, in the present state of our knowledge, to be analogous to mathematical problems in which the number of unknown quantities exceeds the number of equations. In the treatment of all these subjects, we have endeavored to avoid the spirit or the appearance of dogmatism; and have frankly confessed the uncertainty which we feel. We hope, therefore, that from these pages the attentive reader will learn but little that he will have to unlearn in the progress of science.

The two authors whose names appear on the title-page of this Bulletin have freely consulted with each other, and have accepted suggestions from each other in the preparation of their respective parts of the work. In the main the two authors are substantially in agreement in their geological views. It is to be understood, nevertheless, that each is to be held solely responsible for the chapters which bear his name.

The first chapter of the present work is a re-publication, with additions and alterations, of an address before the State Board of Agriculture, published in their Report for 1903. Acknowledgments are due to the officers of the United States Geological Survey for permission liberally accorded to use in the preparation of this Bulletin the unpublished results of the work of the Survey. Acknowledgments are particularly due to Professor W. H. Hobbs, of the University of Wisconsin, who has placed at our disposal the results of his detailed and thorough study of the western part of Connecticut. The contributions of Professor L. G. Westgate, of Ohio Wesleyan University, Dr. H. H. Robinson, of Yale University, and Dr. G. F. Loughlin, of the Massachusetts Institute of Technology, to the study of particular areas of the state, are appropriately acknowledged in the sections of the work relating to those areas. A number

of illustrations are from photographs taken for the United States Geological Survey, under the direction of Professor W. M. Davis, of Harvard University, by whose courtesy they were placed at our disposal. Acknowledgments are also due to Professor Westgate, Dr. Robinson, Mr. Freeman Ward, Professor G. P. Merrill, of the United States National Museum, Mr. Sidney M. Loyd, of Lynchburg, Va., and others, for the use of photographs. Two figures of reptilian tracks on the Triassic sandstones, from Lull's *Fossil Footprints of the Jura-Trias,* are used by permission of author and publisher, the electrotypes being lent to us by the Boston Society of Natural History.

It might have been appropriate to present in this Bulletin a general historical sketch of the work of National and State Surveys and of private individuals in Connecticut. For that information, however, the reader is referred to the pamphlet accompanying the colored Geological Map of Connecticut, published as Bulletin No. 7.

WILLIAM NORTH RICE,
HERBERT ERNEST GREGORY.

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ILLUSTRATIONS

Chapter I

The Geography of Connecticut

As Related to Geological Structure and History

By

WILLIAM NORTH RICE

THE GEOGRAPHY OF CONNECTICUT.

Geographical Divisions. — The State of Connecticut is naturally divided into three areas, which may be called, respectively, the Eastern Highland, the Western Highland, and the Central Lowland.* The Central Lowland may be further divided into a central range of hills and an eastern and a western valley. The eastern valley may not improperly be called the Connecticut Valley, since the Connecticut River flows in this valley from the gorge between Mount Tom and Mount Holyoke in Massachusetts as far south as Middletown.† At Middletown, however, the Connecticut River leaves the Lowland, and flows to the Sound at Saybrook, through a narrow gorge excavated in the corner of the Eastern Highland. The western valley may be conveniently called the Farmington-Quinnipiac Valley. We shall see hereafter that this valley was once occupied by a continuous river, portions of whose course are included in the present Farmington and Quinnipiac.‡ The central hill range extends across the state in an approximately north and south direction, though broken into fragments arranged in parallel and overlapping lines. Parts of the Lowland are traversed by minor hill ranges approximately parallel to the main central range. The accompanying geological map (Fig. 1) shows well these geographical divisions, since the areas of crystalline rocks correspond substantially with the Eastern and Western Highlands, and the large area of Tri-

* The western boundary of the Central Lowland may be traced through the towns of Granby, Canton, Avon, Farmington, Burlington, Bristol, Southington, Cheshire, Prospect, Bethany, Woodbridge, New Haven, and Orange. Its eastern boundary may be traced through the towns of Somers, Ellington, Vernon, Manchester, Glastonbury, Portland, Middletown, Durham, Guilford, North Branford, Branford, and East Haven.

† The whole Central Lowland is often called the Connecticut Valley, especially when the whole of Southern New England, rather than Connecticut alone, is under discussion.

‡ See pages 221 and 253.

assic rocks with the Central Lowland, while the linear areas of the trap rocks mark the position of the hill ranges in the Lowland.

Connecticut is, of course, not isolated in its physical geography from the adjacent states. The Central Lowland extends northward, as a well marked region, nearly to the northern boundary of Massachusetts, and is traversed by the Connecticut River in its course across the state. Farther north the Eastern and Western Highlands coalesce into the great highland region of northern New England and southeastern Canada, bounded by the Hudson-Champlain Valley, the St. Lawrence Valley, and the Atlantic. The Connecticut River flows between Vermont and New Hampshire in a narrow valley contrasting strongly with the broad Central Lowland of Massachusetts and Connecticut. The Highland region in Vermont and New Hampshire attains a greater mean altitude and is dominated by far loftier summits than in Connecticut.

In the edition of the topographical map of Connecticut, which has been published with the forest areas colored green, the distinction of these three districts of the state is very conspicuous. The Eastern and the Western Highland, with the exception of strips along the sea coast, are largely covered by forests, while in the Central Lowland there are no forest areas of any consequence, excepting on the hill ranges already mentioned. The thin, rocky soil of the Highlands is comparatively unattractive for the agriculturist, and large areas have, therefore, been left covered with forests. In recent time, indeed, the area of cultivation in the Highlands has diminished, and the forest has encroached upon the abandoned farms. The deep and fertile soil of the Lowland led to the early settlement of that strip of country, and a large part of the territory was early brought under cultivation. The old towns of Windsor, Hartford, Wethersfield, Middletown, and New Haven are all distributed along the Central Lowland.

The surface of the Highlands is exceedingly rugged, showing very little indeed of level ground. It is, however,

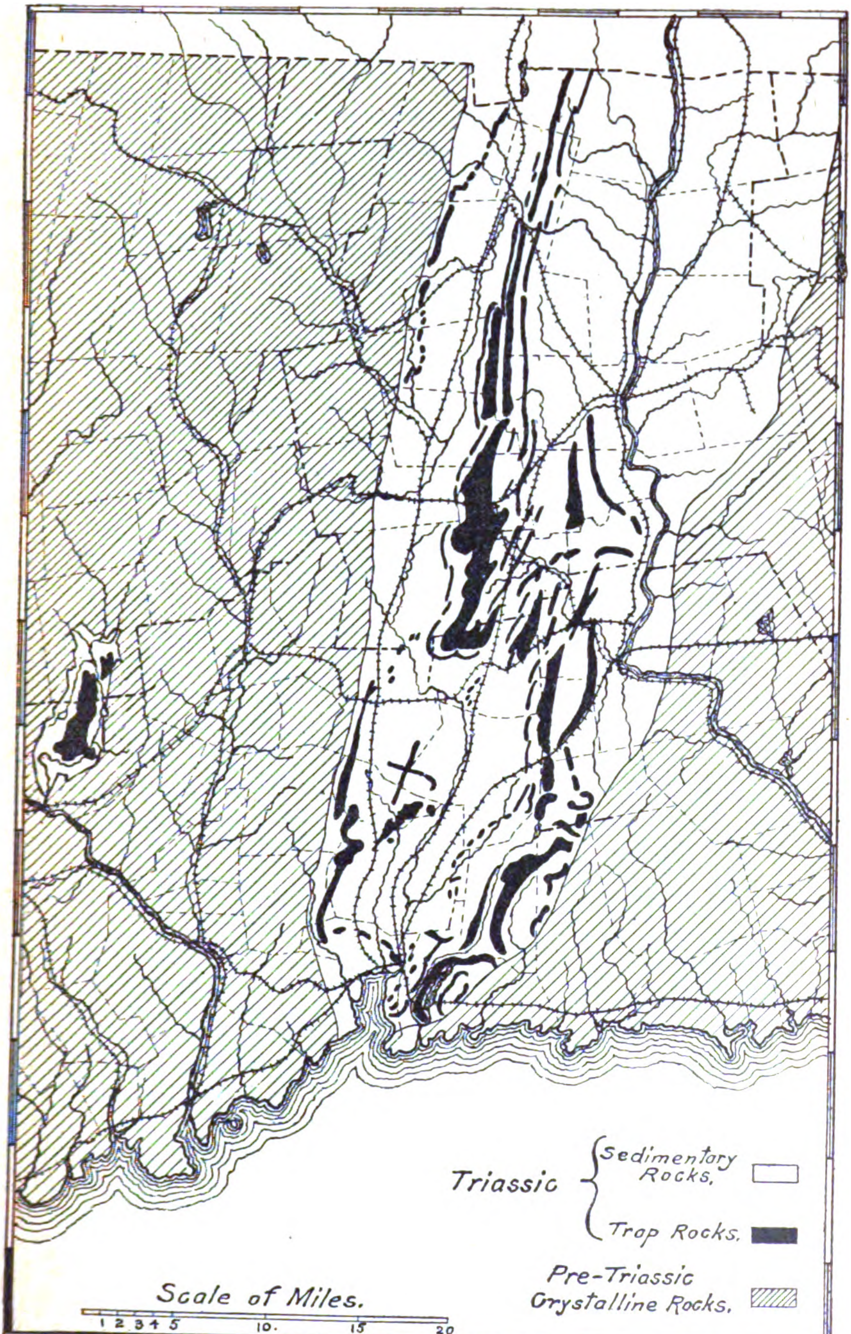


Fig. 1. GEOLOGICAL MAP OF CENTRAL CONNECTICUT.
The large area of Triassic is the Central Lowland; the areas of crystalline rocks are the Highlands.

a remarkable fact that, in almost any general view of either of these highland areas, the sky line appears remarkably straight and nearly level. This appearance is very strikingly shown when the observer stands on West Peak of the Hanging Hills at Meriden,* or on any other high summit of the hill ranges within the Lowland. If we should imagine a sheet of pasteboard resting upon the summits of the highest elevations of Litchfield County and sloping southeastward in an inclined plane, that imaginary sheet of pasteboard would rest on nearly all the summits of both the Eastern and the Western Highlands. This condition obviously suggests the hypothesis that the Eastern and Western Highlands were at one time nearly level plateaus, which have acquired their present rugged surface by the excavation of innumerable valleys. It should be noted also that the hill ranges in the Central Lowland rise to such an altitude that their highest summits do not differ greatly in elevation from the parts of the Highland areas lying to the east and west. Our imaginary sheet of pasteboard, resting on the summits of the rugged Highlands, would touch also many of the culminating points of the hill ranges in the Lowland. These hill ranges present a remarkable uniformity in shape and aspect. They have, in general, as shown in Plate II, a steep face on the west and a gentle slope on the east.

We must now endeavor to correlate these topographical facts with the geological structure of the respective areas; for, as the body without the spirit is dead, so geography without geology is dead also.

Geological Structure of Highlands and Lowland.— If we examine the rocks of the Highlands and the Lowland, respectively, we shall find characteristic differences in many respects. The Lowland rocks are very obviously composed f grains which are rounded more or less perfectly as if ater-worn, and which have evidently been derived from the sintegration of earlier rocks. These rounded grains are stuck together by cementing material, composed largely of

* See Plate I.

PLATE I.

VIEW FROM WEST PEAK, MERIDEN, SOUTHWESTWARD ACROSS CENTRAL LOWLAND TO MOUNT CARMEL AND EDGE OF WESTERN HIGHLAND.

Photograph taken under direction of W. M. Davis, for U. S. Geological Survey.

PLATE II.

LAMENTATION MOUNTAIN AND CHAUNCEY PEAK.

Lamentation Mountain is seen at the left nearly in profile; the west face of Chauncey Peak is seen at the right.
Photograph by L. G. Westgate.

PLATE III.

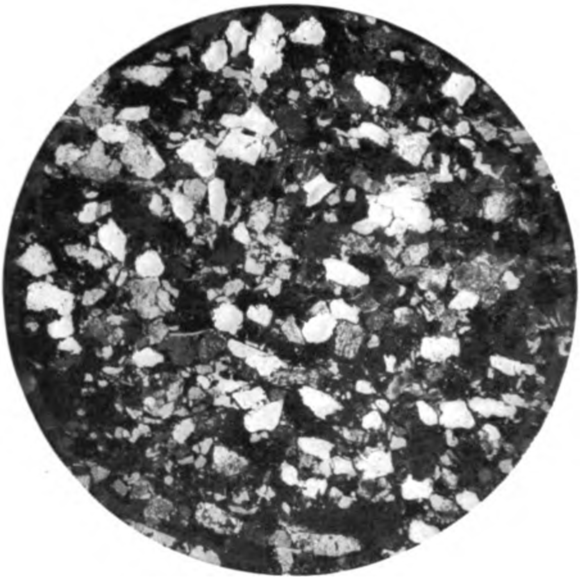


FIG. 1.

FIG. 2.

FIG. 1. Microscopic Section of Sandstone, Portland.
FIG. 2. Microscopic Section of Gneiss, Middletown.

[illegible]n Report on Building Stones, by Hawes, Merrill, and others,
Tenth Census of U. S.

PLATE IV.

SANDSTONE QUARRY, PORTLAND.

Photograph by L. G. Westgate.

red oxide of iron, which fills the chinks between the different grains. In some of the rocks the water-worn fragments are bowlders several inches in diameter; in others, the sandstones proper, the grains are finer, but still large enough to be easily recognized with the naked eye or with a hand lens. In some of the shales the grains are so fine as not to be easily seen without a microscope. When thin sections of these rocks are examined under the microscope, the grains of sand, consisting largely of quartz, but in part of feldspar and other minerals, seem to be translucent, while the cement which fills the chinks between them is nearly opaque. Totally different in character are the rocks of the Highlands. They show no indication of being composed of broken or worn fragments of preexistent rock. They consist of crystalline grains nicely dovetailed together and evidently formed in their present relation to each other. The contrast between the two types of rock, as seen under the microscope, is well shown in Plate III. In technical language, the Lowland rocks are fragmental, the Highland rocks are crystalline.

If, instead of looking in detail at the texture of the rocks of these respective regions, we look at the structures which they show in the mass, we find that the Lowland rocks are arranged in parallel beds or strata, which are sometimes, as in the great quarries of Portland,* almost perfectly horizontal, but which, in most localities, show a moderate dip towards the east or southeast. In the Highland rocks we find sometimes parallel divisional surfaces, giving them an appearance of stratification. In those of the Highland rocks which are thus apparently stratified, the apparent strata are generally tilted up so as to dip at a high angle, and they are often folded and even extremely contorted. In many localities in the Highlands the rocks show no traces of stratification whatever.

These facts of texture and structure show that the Lowland rocks are sediments deposited from water. The Highland rocks are in part rocks which were once deposited as sediments, but which have been so greatly altered by the

* See Plate IV.

action of subterranean heat and pressure and the chemical action of percolating waters and vapors, as to lose entirely their former character of sedimentary rocks. Other parts of the rocks of the Highlands were formed as igneous rocks by solidification from a state of fusion. These igneous rocks, as well as the sedimentary rocks, have for the most part suffered great alteration by subterranean processes, mechanical and chemical. To what has been said in regard to the Lowland rocks, the trap rocks, which are found chiefly in the hill ranges already mentioned, form an exception. These trap rocks are igneous rocks. The trap of most of the ranges in the Central Lowland was poured out in the form of lava sheets, and solidified at the surface; that of the ranges along the western border of the area was injected into fissures between the sedimentary strata.

The actual contact between the rocks of the Highlands and those of the Lowland is visible only at a few points, being generally covered by soil and vegetation. In the ravine of Roaring Brook, in Southington, the relation of the two kinds of rock to each other may be very distinctly seen.* The Lowland rocks rest upon the upturned and water-worn edges of the Highland rocks. Obviously, then, the Highland rocks are older than the Lowland rocks. Moreover, the Highland rocks had suffered the disturbance and alterations which have been already referred to, and had been subjected to more or less erosion, before the deposition of the Lowland rocks.†

Geologic Eons.— Of the four eons into which geological time is divided, the Archæan, Paleozoic, Mesozoic, and Cenozoic, the rocks of the Highlands belong entirely to the first two. It is as yet uncertain how much of the Highland rocks is Archæan and how much is Paleozoic, though probably by far the larger part of the Highland rocks belong to

* A fuller description of this remarkable locality is given on page 81, and is illustrated by Plate XIII.

† In the Pomperaug Valley, in the towns of Woodbury and Southbury, as shown in the map, Fig. 1, there is a small area occupied by rocks of the same character and age as those of the Connecticut Valley. Some further account of this interesting region is given in Chapter III.

the Paleozoic. In Archæan time it is doubtful whether there were any organisms with sufficiently developed skeletons to be preserved as fossils, for only obscure and dubious traces of fossils have been found in rocks of Archæan age. In Paleozoic time there lived a rich and varied fauna of marine invertebrates and fishes, and before the close of Paleozoic time amphibians and even reptiles had appeared. No fossils have been found in the Highland rocks of Connecticut; but it is probable that many of the schists and quartzites of the Highlands, and the marbles of the Housatonic Valley, were once fossiliferous, but have had their fossils obliterated in the alterations by which the rocks have assumed their present crystalline texture. We live in hope that further search may yet reveal here and there a trace of a fossil not quite obliterated, by which we may gain more definite information as to the age of the rocks.

Orogenic Movements.— It has been already remarked that all of the Highland rocks which show indications of stratification have the strata greatly disturbed, tilted up at high angles, and often complexly folded and crumpled. Such great disturbance of the stratification is eminently characteristic of mountain ranges, for mountain ranges are formed by the wrinkling of the earth's crust as it settles down to fit the cooling and contracting interior. The eastern border of North America has been subjected to such orogenic movements at several different times in geological history. One was at the close of the Archæan, one in the middle of the Paleozoic, at the close of the Ordovician, and one at the close of the Paleozoic. As the complete obliteration of fossils renders impossible the exact determination of the ages of the Highland rocks, it is impossible to determine how much of the disturbance which the rocks have suffered may be traced to each of these three orogenic epochs. It is not unlikely that all three of these movements had some share in the disturbance of our Connecticut rocks. Whatever effects they may have experienced in previous orogenic epochs, it is altogether probable that the rocks of Connecticut were considerably disturbed at the last of these

epochs, namely, at the close of the Paleozoic. At that time we know that the rocks of the Appalachian range, from New York to Alabama, experienced the main part of the disturbance they have suffered.

At the close of Paleozoic time it is not unlikely that there were mountain ranges of Alpine height, trending in a general north and south direction, where now we find the rugged but not lofty Highlands of eastern and western Connecticut. A mountain range is no sooner formed by the shrinkage of the earth's interior and by the crumpling of its crust, than the process of degradation begins. The chemical action of the atmosphere and the action of rain and frost crumble down the mountain summits, and the mountain torrents bear the debris to the lowlands, and much of it is ultimately carried by the rivers to the sea. There are at present no high mountains in the world which cannot be proved to have been elevated in times pretty late in the geological scale. Only young mountains can be high, for ancient mountains must have been long since degraded to mere stumps, unless a new epoch of elevation has supervened in the same region.

Connecticut in Early Mesozoic Time.— If, then, we try to make a picture of the area of Connecticut at the beginning of Mesozoic time, we can imagine lofty mountain ranges where now we see the Eastern and Western Highlands. Between these ranges was a long and relatively narrow bay or estuary, occupying the site of the Central Lowland, and extending northward about to the northern boundary of Massachusetts. Into this bay or estuary the torrents which flowed down the sides of the eastern and western mountain ranges bore the debris of the mountains; and this was the origin of the sedimentary rocks, the shales and sandstones and conglomerates, of the Central Lowland. We infer that this bay or estuary did not communicate with the ocean so freely as to be filled with salt water. No marine fossils have been found in any of the rocks of the Connecticut Valley, but remains of fishes which probably lived in fresh or brackish water, and some remains of plants and insects, and

footprints of land animals. The area was apparently a brackish-water estuary, receiving large quantities of fresh water from the mountain streams which came down on each side, and having but a narrow outlet into the ocean. The shallowness of the water over most of this area is indicated by the frequent occurrence of mud-cracks, such as form when a layer of mud left bare by a receding tide or a subsiding freshet dries in the sun. Another striking proof of the shallowness of the water is seen in the tracks of land animals which are found abundantly on many of the layers of the sandstone. The most abundant tracks are three-toed, and look, therefore, much like those of birds. It is probable, however, that in the Triassic era, in which these Connecticut sandstones were deposited, no birds were in existence. The three-toed tracks were probably made by bipedal or semi-bipedal reptiles belonging to the group of dinosauria, an interesting type of animals belonging exclusively to Mesozoic time. About midway between the beginning and the end of the deposition of the sandstones, great fissures were formed in the earth's crust, through which sheets of lava came forth and spread out extensively over the surface. There were, in fact, three of these lava sheets, the first and third comparatively thin, while the middle one was hundreds of feet in thickness. In the intervals between these lava outflows the deposit of sedimentary rock went on quietly, as it did before and after the lava outflows.

At the close of the Triassic era the region of the Central Lowland was elevated so that the bay was drained. The elevation was greater westward than eastward, so that the strata acquired at that time their prevailing easterly dip. It is probably this greater elevation to the west which determined the course of the lower part of the Connecticut River. When the region was elevated and drained, and the estuary accordingly gave place to a river, it would appear that the altitude of the country between Middletown and New Haven was greater than that of the corner of the degraded mountain range between Middletown and Saybrook.*

* For fuller discussion of the history of the Connecticut River, see page 219.

In connection with this elevation and tilting of the sandstones, there occurred also great fractures of the earth's crust with unequal elevation on opposite sides of the cracks. Such dislocations are technically called faults. Some of these faults extended beyond the sandstone area into the area of crystalline rocks; and probably many faults were made at the same time in the crystalline areas.

Connecticut in Middle Mesozoic Time.— A picture of Connecticut in the middle of Mesozoic time, just after the changes which took place at the close of the Triassic, would show, in the regions of the Eastern and Western Highlands, the degraded remnants of mountain ranges of earlier times, while the tilted and unequally elevated blocks of the Connecticut Valley region would show a type of topography not unlike that which now prevails in parts of the Great Basin in the Western United States. There we have the surface marked by a series of ranges, each showing on one side a precipitous cliff marking the elevation of that block above the block on the other side of the crack. Such fault cliffs must have been in the middle of Mesozoic time the conspicuous features of what is now the Lowland; and such cliffs must have added to the ruggedness of the mountain remnants in what is now the Highlands. In later Mesozoic time there occurred no uplifting and no crumpling of the strata; and the agencies of the atmosphere and water and ice, tending to degrade the level of the country and to smooth out its inequalities, had things all their own way.

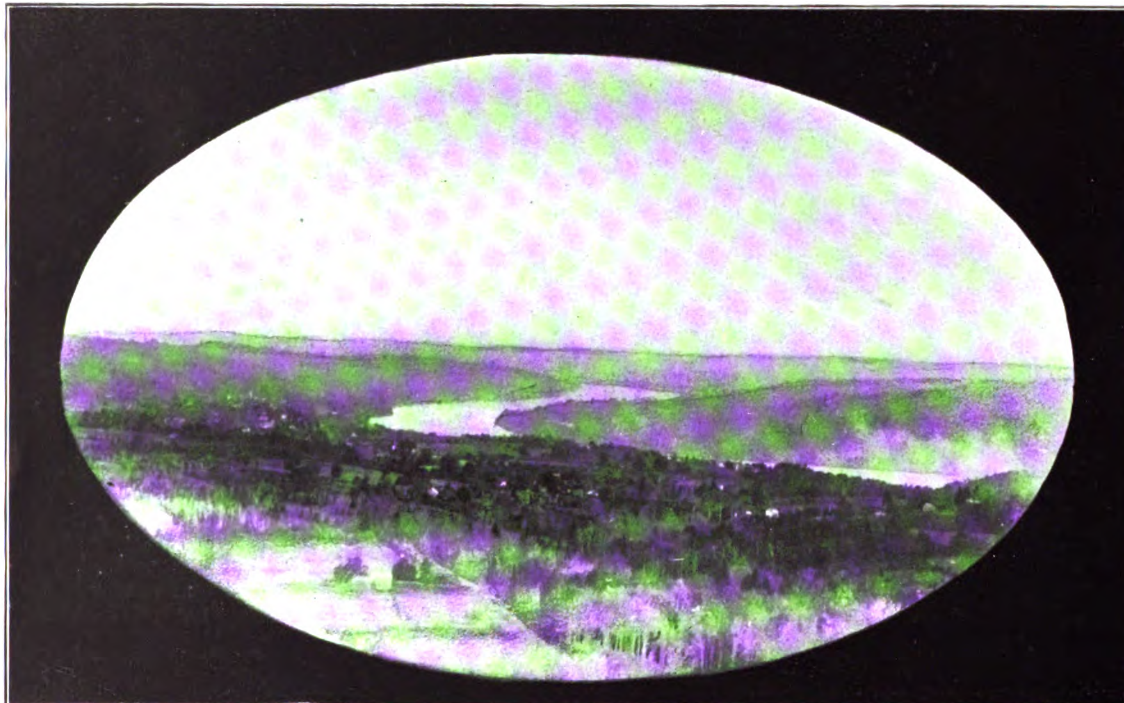
Denudation.— Every one is aware, in a general way, that swift streams tend to erode their banks and beds, while sluggish streams tend to deposit sediment; but only those who have made some study of the subject appreciate the great effect of a slight change in the velocity of the current. The weight of the pieces of rock which can be carried by a river current varies as the sixth power of the velocity. If the velocity of a stream is doubled, it can carry a stone sixty-four times as heavy as the largest stone it could move before; if the velocity of the stream is increased tenfold, it

can carry a block a million times as large as it could carry before. The energy of the stream is the energy of a falling body; and, in accordance with the principles of physics, that energy is measured by the product of the mass into the vertical height of the fall. The conditions of a river, however, are very different from those of a body falling freely with only atmospheric resistance. Such a body falls with continually accelerated velocity; and, if the height of the fall is considerable, the body possesses at the bottom of the fall a tremendous store of energy, which may be converted into heat or may produce other striking effects. A river, on the other hand, has generally at its mouth a velocity which is almost zero, showing that its energy has been mostly expended along its course, instead of being accumulated to take effect at the end of the journey. The energy of a stream is, in fact, generally nearly all expended, partly in friction and partly in transportation of sediment. The sand and pebbles which a river carries have a specific gravity two and one-half to three and one-half times as great as that of the water, and they must, therefore, be lifted in opposition to gravity by upward eddies in the water in order that they may be transported. The larger the amount of energy which is expended in transportation, the smaller will be the residue which can be expended in overcoming friction. It follows, then, that the greater the amount of sediment the less will be the velocity of the stream; and, in turn, the less the velocity the less the competency of the stream to carry the coarser grains of sediment. As a result of these dynamic principles, we have the general law that every stream tends to shape its bed to a slope which will give the stream just sufficient velocity to carry the load of sediment which is furnished to it by rain wash and by tributary streams. That slope, for each stream, or part of a stream, is called the profile of equilibrium, and every stream tends to shape its bed to such a profile. Where the bed is too low, sediment is deposited till it is filled; where the bed is too high, the stream erodes till it is reduced to the proper profile. If, now, we assume that any part of a stream is graded ap-

proximately to its profile of equilibrium, its velocity, on an average, will be just sufficient to carry its load of sediment: on the average it will tend neither to cut nor to fill. But, if the course of the stream is a little sinuous, the velocity near the concave bank will be in excess of the average velocity, while the velocity near the convex bank will be less than the average velocity. If the average velocity is just sufficient to carry the load, neither cutting nor filling, the tendency will be to deposit sediment near the convex bank and to erode the concave bank. The sinuosity thus becomes exaggerated into a great horseshoe-shaped bend, or oxbow: as this process continues, the two ends of the oxbow come closer together, until finally, most likely in some time of freshet, the stream cuts across and straightens out its course, leaving a horseshoe-shaped lake of nearly stagnant water at the side of the main current of the stream. Thus, when a stream has worked down nearly to its profile of equilibrium, meander after meander is formed and destroyed, until a strip of country many miles wide, in case of a large river, is graded to an almost perfect plane. While the main streams of a stationary region are thus widening their valleys into plains, and this process is gradually extending towards the headwaters of the main streams and their tributaries, the action of the atmosphere and rain and frost is continually degrading the country between the streams. The divides, which in an earlier stage of development have been strongly defined ridges, are gradually flattened down to low altitudes and almost imperceptible slopes. It is evident, then, that in process of time any country that is exposed to the atmospheric and aqueous agencies of denudation, in the absence of any renewed uplift of the land, will be gradually reduced to a nearly level surface. In such a country the streams will lazily meander over the broad plains which they have formed, and which are but slightly depressed below the general level of the country. A country in such a condition is called a peneplain.

The Peneplain of Southern New England.— At the close of Mesozoic time the whole area of Connecticut, and, for that

PLATE V.



INTRENCHED MEANDERS OF CONNECTICUT RIVER IN EASTERN HIGHLAND FROM GREAT HILL (Cobalt Mountain
Photograph by L. G. Westgate.

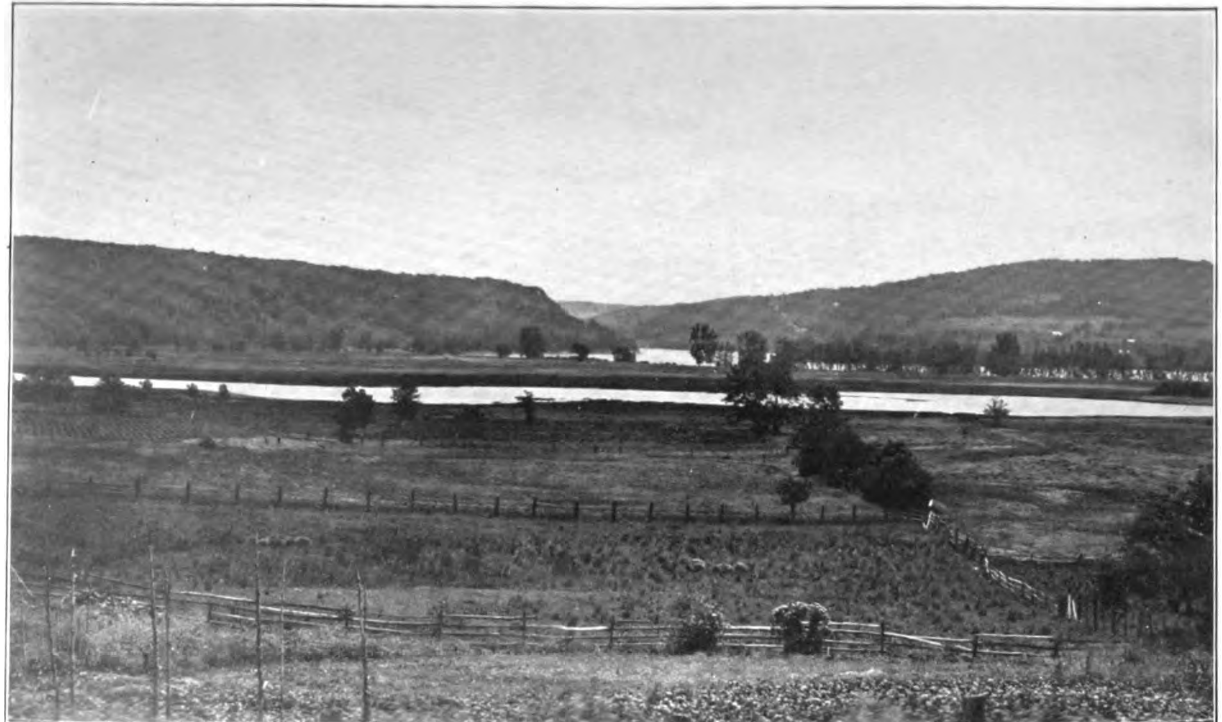
matter, the whole area of southern New England, had been reduced to the condition of a peneplain. The remnants of mountains in the Eastern and Western Highlands, and the cliffs formed by the tilted and faulted blocks of the Central Lowland, had all been substantially planed away. The whole country was nearly flat, no part of it much above the sea level; and the rivers crawled slowly in broad serpentine curves over the great plains which they had leveled. If anyone looks at the course of the lower Connecticut, as seen in the beautiful panorama from Cobalt Mountain, or Great Hill, near the boundary of Portland and Chatham (shown in Plate V), he will see that the river, though occupying a narrow gorge, swings in broad serpentine curves. A river does not stop to make such curves when it is flowing down a steep slope towards the sea. The curves of the lower Connecticut are the curves which the river took in the old days of the peneplain. Though the country has since been elevated, and the river has had to carve a gorge, it has carved that gorge not in a straight but in a serpentine course, because it had to stay in the course which it had shaped out for itself before the uplift.

The Tertiary Uplift.— The formation of the peneplain of Southern New England was probably completed about the end of Mesozoic time. Early in the Tertiary era of Cenozoic time there came a re-elevation of the country. This time there seems to have been no folding or faulting of the strata, but a gentle uplift of the whole country into an inclined plane which, at the northwest corner of Connecticut, was about half a mile above the sea level, and which sloped gently to the southeast.* At this time, of course, the rivers entered upon a new cycle of erosion. The uplift gave them a steeper slope, a higher velocity, and a great revival of erosive power; and they began to carve out a new system of valleys in the country that had been so nearly featureless just before. In the work of this new cycle of erosion the

*This southeastward slope of the uplifted peneplain of southern New England probably represents one side of a broad and gentle arch of the earth's crust (geanticline) whose axis passed near the northwestern corner of Connecticut.

unequal resistance offered by the sedimentary rocks of the Lowland and the crystalline rocks of the Highlands wrought a striking effect. On the soft Lowland sandstones the streams quickly wore down nearly to a profile of equilibrium, and began to swing sideways and to widen out their valleys into plains, while the ridges between were rapidly worn down by the action of the atmosphere and rain and frost. By these processes the region of the Central Lowland has been brought to a condition somewhat approaching that of a peneplain. An exception sometimes proves a rule; and the high ridges which mark the outcrops of the hard sheets of lava or trap emphasize the degradation which the areas of weaker rocks around them have suffered. The principal trap range in the center of the Lowland, separating the Connecticut Valley from the Farmington-Quinnipiac Valley, marks the outcrop of the massive lava sheet, the second in the series of lava outflows. While the agencies of denudation have reduced the sandstone region far towards the condition of a peneplain, the streams on the hard Highland rocks have been able in the same time only to excavate narrow trenches, and the regions between the streams have suffered but little degradation. In the case of rivers whose course is partly in the Triassic and partly in the crystalline area, there is generally a strongly marked change in the character of the valley at the boundary between the two formations. The Connecticut River above Middletown flows in a broad valley whose filling of drift has been carved into broad terraces and flood plains, while below Middletown it flows in a narrow, steep-walled gorge. Plate VI shows the head of the gorge, which contrasts strongly with the open valley shown in the foreground. The valley in the sandstones shows the character of age, that in the crystallines the character of youth, though the excavation of both was commenced when the peneplain was uplifted. It is a striking illustration of the principle that youth and age in river valleys are measured not by centuries but by stages of development. The broad features of the present topography of Connecticut are due, then, simply to the unequal re-

PLATE VI.



CONNECTICUT RIVER BELOW MIDDLETOWN.

The narrow gorge in the crystalline rocks is shown in contrast with the broad, flood-plained valley in the Triassic. Pecausett Pond divides the broad area of flood-plain in the foreground. Photograph by L. G. Westgate.

sistance of the Highland and Lowland rocks, respectively, in the new cycle of erosion initiated by the uplift which occurred at the beginning of Tertiary time. The strong crystalline rocks of the Highland areas are left today in the condition of plateau remnants gashed by innumerable valleys, while the weak rocks of the Central Lowland have been degraded to a comparatively low altitude and a comparatively smooth surface.*

If, in the post-Triassic elevation, the area of the Central Lowland had been uplifted and tilted without faulting, there would have been one substantially continuous range of trap extending from north to south through the area. It has been, however, already remarked that, at the time of this uplift and tilting, the crust was broken by numerous cracks, and the blocks on opposite sides of the cracks were unequally elevated. The principal faults in the part of the Triassic area south of Hartford were developed along cracks having in general a northeast and southwest trend; and in general the southeast side of the crack went up, and the northwest side relatively went down. Each block was tilted so that its western side was higher than its eastern; and the west side of the block on the east of each crack rose in a mighty wall above the east side of the western block. As has been already stated, all these cliffs were planed away in the formation of the great peneplain in later Mesozoic time. But these faults have a great influence upon the present topography, in that they have broken the line of outcrop of the great trap sheet, which would otherwise have been continuous, into a series of short lines which, in general, are shifted farther and farther to the east as we go southward from the latitude of Hartford. The Hanging Hills of Meriden, the range of Lamentation, the Higby-Beseck range, and the Saltonstall range east of New Haven, are thus parts of the outcropping edge of the same

* In the northwest corner of the state, the Housatonic River flows for a few miles in a valley of considerable breadth, as is the case farther north in Berkshire County, Massachusetts. In this case, the reason for the breadth of the valley is the existence of a limestone formation, which is easily eroded on account of the solubility of the material.

vast lava sheet, broken apart, and arranged in parallel and overlapping lines, as the result of the great series of faults. The form of these trap hills is the simple and obvious result of the unequal resistance of the rocks and the tilting of the strata. The gentle eastward slope of the trap hills corresponds simply to the dip of the strata; the overlying sandstones have been removed, and the whole gentle slope of the hill is formed by the sheet of lava. On the west side, where the soft sandstones are exposed beneath the trap, the agencies of erosion have carved down to the general level of the valley, thus giving the almost precipitous west face which in general characterizes these hills.

The Glacial Period.— The broad features of the present geography of Connecticut were substantially completed in Tertiary time; but important modifications in detail are due to the events of Quaternary time, and especially to the action of the great ice sheet in the Glacial period. At the beginning of Quaternary time, glaciers developed in the highlands between Hudson Bay and the Saint Lawrence, which became confluent into a vast ice sheet, blending on the west with the ice sheet that covered the northern part of the great Western Cordillera. This sea of ice extended southward over Canada, New England, and the northeastern United States in general, at one point even crossing the Ohio River and extending a little distance into Kentucky. The extent of the glaciated area is shown on the map, Fig. 18, p. 230. Over most of New England the general course of the ice movement was somewhat east of south.* It scraped off the products of rock disintegration, the soils and subsoils and masses of rotten rock which had been slowly accumulating in the long ages since Paleozoic time. It ground into the solid rocks which lay beneath the rotten rock; and everywhere the rocks were marked with that smooth and polished surface and those parallel striæ and grooves which are so conspicuous whenever we uncover a fresh surface of

* See map, Fig. 19, page 239.

bed rock, and which tell their unmistakable story of glacial action.* Much of the old accumulation of soil which was thus scraped up by the glacier must have been carried into the sea. When the climate grew milder again, and the ice sheets gradually melted away, the country was left covered with a sheet of the heterogeneous deposit known under the name of *till*.† It consists partly of the remnants of the old mantle of disintegrated and decomposed rock, partly of fragments worn and torn from the underlying unaltered rocks by the action of the glacier. Its most marked characteristic is its heterogeneousness; fine sand, clay, and pebbles, and bowlders weighing many tons, are heaped confusedly together. Rarely in New England can we find in an excavation, either natural or artificial, that passage by fine gradations from solid rock through rotten rock and subsoil to the surface soil, which is so commonly observed in the unglaciated regions of the Southern States. Far more commonly in New England we find the heterogeneous mass of till resting without any gradation upon almost unaltered rock. The contrast in this respect between the conditions in New England and those in the region south of the glaciated area is shown in Plate XXV.

Some minor topographical features are connected with the distribution of the drift. While in some places the ice seems to have scraped down into the unaltered rock and shoved along all the debris, in other places the ice seems to have ridden up over great masses of till; and, when the ice sheet melted away, these great masses of till were left as low, flat domes, sometimes nearly circular in outline, but often elliptical, with the major axis of the ellipse trending nearly in the direction of the ice movement. Such dome-shaped hills are called drumlins, and in some parts of Connecticut they are very conspicuous features in the landscape. One of these drumlins, near Highland Park, in Manchester, is shown in Plate XXX.

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*See Plate XXVII.

† The till, and the aqueous and aqueo-glacial deposits, more or less distinctly stratified, associated with the till, are included under the name *drift*.

There is reason to believe that at the beginning of the Glacial period the continents, at least in their northern portion, stood at a somewhat higher level than at present, and that greater elevation of the land was probably the cause of the glacial climate. Elevation of land has a certain amount of direct effect in lowering the temperature; but it has recently been shown to be probable that a general continental elevation has a much more important indirect effect upon the climate by reason of a complicated series of changes resulting in a diminution of the amount of carbon dioxide in the atmosphere, allowing a more rapid loss of heat by radiation from the earth's surface into space.* While the country at the beginning of the Glacial period probably stood at a higher level than at present, it seems certain that at the time of the final melting of the ice sheet the country was depressed to a somewhat lower level than at present. This lower level of land, of course, diminished the power of the streams for erosion and transportation, and caused the valleys which had been excavated in bed rock to be largely filled up with drift. To some extent, indeed, the valleys had come to be filled with the unstratified and heterogeneous till shoved into them by the movement of the glacier. But there are also in most of the valleys extensive deposits of sand and gravel and clay, sorted and stratified by water, which were undoubtedly deposited by the waters of the streams whose velocity was checked by subsidence, and which in parts were dammed up by accumulations of drift and converted into lakes. Between Hartford and Middletown there are extensive deposits of this stratified material rising to a height of about two hundred feet above the present level of the river. As these sediments along the lower Connecticut were probably deposited at sea level, or a very little above sea level, it may be inferred that the post-Glacial subsidence carried that part of the valley between Hartford and Middletown nearly two

*Chamberlin, in *Journal of Geology*, vol. VI, pp. 449, 597, 609, vol. VII, pp. 545, 667. The theory of climatic changes developed in these articles is not, however, universally accepted. See Hann, *Handbook of Climatology*, Part I, p. 398.

PLATE VII.

TERRACE AND FLOOD PLAIN, GLASTONBURY.
Photograph by L. G. Westgate.

hundred feet below its present level. The amount of the subsidence diminished to only a few feet at Long Island Sound, but increased northward. In the Saint Lawrence Valley marine sediments were deposited at that time which are now about five hundred feet above the sea level. In the valley of the Connecticut these river deposits attained in places a width of ten miles. It must not, however, be inferred that the Connecticut River was ten miles wide at that time. Rather must we infer that the river wandered in meanders over that belt of country, excavating here and depositing there, rapidly changing its course from time to time, and, in places, distributing itself into branches which reunited below, inclosing islands in the network of river channels.

The latest geographical change chronicled for this region is the slight re-elevation by which the country assumed, substantially, its present level. As this elevation, like the previous subsidence, was greater towards the north, southward-flowing streams gained again increased velocity and increased power of erosion and transportation; and new flood plains were accordingly formed at a lower level than the broad plains over which the river had been lately meandering. Remnants of these broad plains of drift may generally be recognized on one side or on both sides of the valley, forming those terraces which are so characteristic a feature of the scenery of New England and other portions of the glaciated region. Plate VII shows a portion of one of these terraces and the modern flood plain. Sometimes, as in the locality represented in Plate VII, we find a single abrupt descent from a high terrace to the modern flood plain, while in other places stages in the process of elevation and erosion are marked on one or both sides of the stream by intermediate terraces rising like flights of stairs. The Connecticut River, within the limits of our state, seldom shows more than one or two intermediate terraces, and generally none at all; while along the northern part of the river, in New Hampshire and Vermont, numerous terraces are often shown. Numerous terraces are shown also on many of the

tributaries of the Connecticut. The difference between the upper and the lower Connecticut, as regards the development of intermediate terraces, is probably correlated with the fact that at the time of the post-Glacial subsidence, when the great deposits of stratified drift were formed, the upper Connecticut occupied a comparatively narrow valley, while the lower Connecticut was a tidal estuary of great breadth. The condition of the formation of intermediate terraces is generally that the river, in the lateral extension of its meanders, encounters ledges of rock or hard masses of till.* This would naturally occur more frequently in the excavation of a channel in a comparatively narrow valley than in the excavation of a channel in such a mass of drift as filled the broad estuary of the lower Connecticut.

The filling of the old valleys by drift, and the consequent disturbance of the drainage system of the region, have resulted in the formation of innumerable waterfalls. In many cases rapids or falls have been produced where a stream, meandering over the broad drift plain which filled its ancient valley, was flowing on the edge of the plain where the sheet of drift was thin. In such cases, as the land rose and the river began to erode its bed, the deepening of the channel would be quickly arrested when the river in its down-cutting came to the hard bed-rock below the capping of drift. If, for some miles down the stream, the river was flowing near the middle of the drift plain, where the drift sheet was thick, a very steep slope would naturally be developed from the shallow portion of the channel carved where the drift was thin into the deeper channel carved in the thicker mass of drift. In other cases, however, streams were completely turned aside from their old courses, and forced to carve for a greater or less distance entirely new valleys.† Waterfalls or rapids would naturally be developed wherever ledges of especially resistant rock retarded the erosive action of the river. Plate VIII shows a beautiful example of one of

* Davis, *River Terraces in New England*, in *Bull. Museum of Comparative Zoology*, vol. XXXVIII.

† For an illustration of this condition, see discussion of changes of drainage in the Farmington-Quinnipiac Valley, pages 221, 251.

PLATE VIII.

WESTFIELD FALLS.

The fall began at the mouth of the gorge, in the foreground of the picture, where the sheet of trap is cut off by a fault. The gorge shows the recession of the falls.

Photograph taken under direction of W. M. Davis for U. S. Geological Survey.

these waterfalls. The fall obviously began where the hard sheet of trap was cut off by a fault. The little gorge shown in the picture below the falls has the character of an extremely young valley, and is obviously post-Glacial. Waterfalls are always short-lived with reference to the scale of geological time, since the river in time wears away the ledges which at first had resisted its erosive action, and shapes the whole length of its channel to a profile of equilibrium. In regions where the drainage system has long remained undisturbed, as in the southern states of our country, waterfalls are rare, since the rivers have had time to plane down to a profile of equilibrium nearly the whole of their channels. The innumerable waterfalls of New England and the adjacent states are the result of the disturbance of the drainage system resulting from the Glacial period.

Another effect of the disturbance of the drainage system of this region by the deposits of drift is seen in the abundance of lakes. Lakes, like waterfalls, are geologically short-lived. The inflowing streams deposit sediment that tends to fill the lakes; the outflowing streams gradually lower their channels and tend to drain them. When a watercourse has shaped itself to a profile of equilibrium, all lakes along its course will have disappeared. Some of the lakes are formed by masses of drift which have dammed up portions of old valleys. Some small ponds occupy the depressions called kettle-holes, which have been produced by the settling down of the sand and gravel where masses of ice were melting which had been buried in the drift.

One interesting effect of the changes of level in Quaternary time has been the drowning of the lower parts of our rivers, forming thereby the harbors along our coast. Long Island Sound, in fact, is a large example of a drowned river valley.

The action of the ice sheets in scraping off the soils which had resulted from the processes of rock decomposition and rock disintegration that had been going on for ages, and transporting much of that disintegrated material to the sea, probably resulted in a decided deterioration of

our territory as regards adaptation for agriculture. The changes of Quaternary time, however, have afforded abundant compensation for their injury to the agricultural interests of the State by providing us with an unlimited supply of water-power for manufactures and with harbors well adapted for commerce.

Summary.— The relation of the successive changes of geological history to the present geography and topography of Connecticut may be briefly summed up in the following statements: — The rocks of the Highlands acquired their present crystalline character in connection with the orogenic movements of Archæan and Paleozoic time. The sedimentary rocks of the Central Lowland were deposited in Triassic time, and were derived from the waste of the mountain ranges which may then have existed in the regions of the present Highlands. The draining of the Connecticut estuary occurred at the close of Triassic time. The whole area of Connecticut was reduced to a peneplain in later Mesozoic time. A general elevation of the country in Tertiary time led to the development of the broad features of the present topography. While the action of erosion on the soft rocks of the Central Lowland was able to reduce that part of the state again to a condition approaching a peneplain, in the same lapse of time the streams working on the hard rocks of the Highlands could only carve narrow, gorge-like valleys. While the broad features of the topography were shaped in Tertiary time, many minor details, such as drumlins,, river terraces,* waterfalls, lakes, and harbors, were due to the changes of Quaternary time.

* The deposits of stratified drift forming the terraces have been described on page 34 as formed in the valleys after the retirement of the ice. According to this view the terraces are remnants of plains of stratified drift which once extended across the valleys. This is probably the true explanation of many of the terraces. But recent investigations show that probably some of the terraces (particularly in the lower or estuarine portions of the larger rivers) were formed as delta deposits along the sides of the valleys, while tongues of ice extending beyond the general line of the receding ice sheet still occupied the central part of the valleys.

Chapter II

The Crystalline Rocks

By

HERBERT ERNEST GREGORY

THE CRYSTALLINE ROCKS.

PART I.

GENERAL PRINCIPLES.*

INTRODUCTION.

With the exception of the rocks of Triassic age, described in Chapter III, the entire state of Connecticut is underlain by crystalline rocks of very great antiquity. As indicated on the maps (Fig. 1, page 19, and Plate XIV), the Triassic areas cover about 1,000 square miles, and the *Ancient Crystallines* occupy the remainder of the 4,990 square miles which make up the state. Thus, the crystalline rocks may be said to constitute the floor of the state and to be the characteristic rock formation. They everywhere surround and underlie the sandstones and lavas of a later age.

This widespread distribution of crystalline rocks as compared with unaltered sedimentary deposits is characteristic of New England as a whole, as well as of the state of Connecticut. Small areas of slightly changed sediments are found in Rhode Island, and in central and eastern Massachusetts. Vermont and New Hampshire also have representatives of this class of rocks. Maine has fossiliferous sediments in several localities, particularly in the Aroostook region. Considered as a whole, however, rocks other than crystalline are rare in New England; and the region is clearly a geological province of metamorphosed, crystalline rocks, varied here and there by areas consisting of other types.

The ancient rocks of the crystalline tracts differ radically from the sandstones and traps of the Connecticut and Pomperaug valleys. As a rule, we find simplicity and reason-

* It is here taken for granted that the reader has a knowledge of elementary geology, at least so far as to be acquainted with the chief mineral species and common rocks, the geological ages, and the main geological processes.

able uniformity in the latter, while complexity and variety characterize the former. The method of origin and history of the sandstones are fairly well known, yet we are ignorant of the meaning of many structures in the crystallines, and the origin of certain rocks in Connecticut is shrouded in mystery. An explanation of sedimentary rocks requires a knowledge of the forces operating at the present time on the surface of the earth. It is necessary to understand the action of rivers, winds, ice, etc. A complete understanding of the crystallines involves a knowledge of the forces which are at work within the interior of the earth, as well as an understanding of the chemical and mineralogical composition of the rocks as they exist. Much detailed study is required; and the cooperation of physicists, chemists, and geologists is necessary to solve the problems presented by metamorphic rocks. It is but fair to state that data are not at hand and methods have not as yet been developed which make it possible completely to understand the composition, structure, origin, and history of many rocks within the state. Geological science is not sufficiently advanced to solve the problems offered by some of our most widespread rock formations. The reader should therefore not be discouraged at his inability fully to understand the geology of his locality, and to recognize readily the innumerable varieties of rock which he finds in the ledges or scattered along the roadsides throughout the area of the ancient crystallines. An additional difficulty confronts the student of Connecticut geology in that some of the bowlders built into fences or strewn over the field cannot be traced to their parent ledge within the state, and a knowledge of the geology of the regions to the north may be necessary before the history of a roadside pebble can be interpreted.*

Although it is impossible to give a complete account of the origin and history of the ancient crystallines, many facts about them are known; and it is the purpose of this chapter to present these facts, and to explain the characteristic

* These bowlders which have been brought to the state by the great ice-sheet of the Glacial period are explained more fully in chapter IV.

features of the geological formations found within the state both east and west of the Triassic areas.

SEDIMENTARY, IGNEOUS, AND METAMORPHIC ROCKS.

For the convenience of students of science, rocks have been divided into three classes: sedimentary, igneous, and metamorphic. Each of these classes is represented in Connecticut by many varieties.

Sedimentary Rocks.— The sedimentary rocks are those which have been laid down by water. They are muds, sands, gravels, and ground-up shells, which have been cemented and pressed into solid rock. Such are the shale beds at Saltonstall, Durham, and Bloomfield; the sandstones at Portland, Tariffville, and Windsor; the conglomerates at Fair Haven and Meriden; and the thin beds of limestone west of the main lava ridges in Northford and Southington. The shales, sandstones, and conglomerates are made of fragments of other rocks, and their composition and structure reveal their history. Sandstone tells the story of a preexisting land area, of the action of frost, wind, and ice, which disintegrated the original rock, and of moving water in the form of rivers or waves which carried the broken material to a place of rest. The cement between the individual grains tells of the presence of water carrying mineral matter in solution. Thus it is with other sedimentary rocks; each contains within itself a more or less legible life history.

Igneous Rocks.— Igneous rocks have been once molten and have solidified by cooling. They are therefore typically composed of crystals, as compared with sedimentary rocks, which are formed of broken fragments. In accordance with their chemical and mineral composition, igneous rocks are divided into a great number of species — granite, syenite, diorite, basalt, etc. The conditions under which these rocks cooled have made a great difference in their texture; hence we find fine-grained granites like those from Millstone Point and coarse-grained rocks like those

quarried at Stony Creek. The history of an igneous rock is revealed by an examination of its composition, texture, and structure; thus, for example, it is known that the diabase of East Rock at New Haven was forced into the sandstone and cooled below the surface of the earth; that the rock of Talcott Mountain is basalt, formed on the surface as a lava flow; that the granite rock quarried at Waterford cooled at a very great depth below the surface.

The sedimentary rocks of Connecticut are confined to the Triassic areas — the Connecticut Valley and the Pomperaug Valley. The unchanged igneous rocks have a large development within the Triassic, and are present in small amounts throughout the State. The rocks of these two types require no explanation beyond that given in ordinary text-books. The great mass of Connecticut rocks, forming the ledges and distributed as loose bowlders, belong to the third class, the metamorphic, and require special explanation.

Metamorphic Rocks.— Metamorphism is a term introduced by Lyell as the name of a process by which rocks are profoundly changed from their original condition. The rocks resulting from such changes are called *metamorphic*. The early geologists believed that metamorphic rocks were always modified forms of sedimentary deposits, but it is now known that the original rock may have been either sedimentary or igneous, and metamorphic rocks themselves may be changed again and again. Metamorphism is in general a change in the direction of greater induration and more complete crystallization. The amount of metamorphism which takes place may be slight, as in the case of a clay hardened by contact with heated rock. The great areas of metamorphic rock, however, have undergone much greater changes in texture, composition, and structure—changes so far-reaching that in many cases it is impossible to determine the nature of the original rock. Changes of this sort have occurred in the Connecticut crystallines, and their appearance is so altered that the original rocks and their metamorphic

equivalents would be naturally classed as unrelated types. They have been thus classed in the past, as the older geologic maps will show, and it is reasonable to expect that eventually groups of rock which we now distinguish will be found to be different phases of the same formation. Only an expert geologist is able to see an ancient diabase in the chlorite schist of Milford, and to recognize that the micaceous rock of Bolton Notch formerly existed as mud.

A striking feature of the Connecticut crystallines is the absence of fossils. So great have been the changes induced by heat and pressure that all traces of former life have been destroyed. Not even a fragment of a fossil has been found in these rocks within the limits of the state. The far-reaching importance of this fact is at once seen when we realize that fossils are a means of finally determining the geological age of rocks, and that, owing to the absence of these remains, the age of the crystallines in Connecticut is unknown. We have proof that the metamorphic rocks are older than the sandstones, which are of Triassic age, because they lie unconformably beneath the strata of the Farmington Valley; but whether they are mostly Cambro-Silurian or Carboniferous, or whether some are Archæan, and representatives of all the Paleozoic ages are present, is not known. This absence of fossils makes of little value the ordinary methods of determining the relations of the various formations, and we must learn what we can from a study of the composition, texture, and structure of the rocks themselves.

PRINCIPLES OF METAMORPHISM.

Because the structure of metamorphic rocks is so entirely different from that of sedimentary and igneous types, and because their origin is due to forces which have not operated in the case of the unmetamorphosed varieties, it may be found helpful to discuss briefly the physical and chemical principles underlying metamorphism.*

*For a complete discussion of these principles, see Van Hise, *A Treatise on Metamorphism*, U. S. Geological Survey, Monograph XLVII.

Contact Metamorphism.— Metamorphism may result from exceptional heat applied to rocks, in which case the process is largely one of expulsion of water and hardening and discoloration, with partial fusion. The process is well exhibited at the margin of the dikes cutting the sandstone of the Fair Haven tunnel, where the sandstone is hardened by contact with the molten material; and is very much like the process of brick-making. Elsewhere in the area covered by the Triassic rocks this process of local metamorphism by contact with hot rock is well shown.

Metamorphism usually, and always on a large scale, is the result of heat combined with great lateral pressure. The metamorphic crystallines of Connecticut, as well as most other metamorphic rocks, are the result of widespread activity on the part of forces acting below the earth's surface.

Movements of Rock under Pressure.— In shrinking, the earth requires a continuous adjustment of the outer zone to the interior; and various minor adjustments are due to the fact that parts of the earth's surface are weighed down by the accumulation of sediments, while other parts are having material removed by erosion. The result of these and other causes is that rocks are continually subjected to strain, and when found in nature are much or little affected, according to the amount and the character of the thrust. The chief factors which control the deformation of a rock mass under a given thrust are the thickness, strength, and composition of the rock, and the character and thickness of the materials which enclose it above and below. The pressure exerted by thousands of feet of strata causes deeply buried rock masses to behave quite differently from those at the earth's surface. In accordance with these principles three zones within the earth are distinguished; namely, the zone of fracture, the zone of flowage, and the zone of combined fracture and flowage. In each of these, rocks are differently affected and certain characteristic structures are developed.

Zone of Fracture.— When rocks at the earth's surface are subjected to lateral pressure, they break, and leave crevices, small or large, between the broken parts. This condition holds true of rocks below the earth's surface down to a depth where the weight above them is greater than the strength of the rock to resist. The fracture may appear at the surface as a fault, joint, or mass of crushed rocks, held firmly in place. Often the fractures are innumerable and extend in one direction over a wide area. Rocks so located in the earth that they break when subjected to pressure are said to be in the *zone of fracture.* The depth of this zone below the earth's surface varies with the strength of the rock; but even for the most rigid rocks there comes a place, never at a great depth in comparison with the earth's diameter, where the weight of the rocks above exceeds the ultimate strength of the rock beneath; and here no joint, or fracture, or cavity of any sort can exist. In the case of soft shales, this depth may not exceed 2,000 feet, while in the strongest rocks known it is probably not over 30,000 feet. At these depths no permanent crevice can exist, and if a fracture should occur the parts would be soon actually welded together.

The sandstones and lavas of the Connecticut Valley are now in the zone of fracture, and were in that zone when the displacements occurred which destroyed the continuity of the strata. They are traversed by innumerable faults, zones of brecciated rock, and systems of parallel joints. They have adjusted themselves to the lateral strain by breaking and by the slipping of the broken parts past each other. It is partly to this fact that we owe the preservation of the Triassic strata, for the sandstones and lavas have been broken and depressed below the general level of the country, and hence preserved from erosion during the long periods that have elapsed since Triassic time. The metamorphic crystalline rocks likewise are now in the zone of fracture, but their character and structure were already present when they were brought to that zone by erosion of the overlying mass.

Zone of Flowage.— Within the earth's surface, at a depth of about 30.000 feet, the conditions are very different from those just described. The weight of the strata above exceeds the strength of the rock to resist, and cracks and crevices cannot form. The rocks are everywhere subjected to compression, and the materials composing them attain equilibrium by moving from a place of greater to one of less pressure. The material composing the rocks adjusts itself, not by sudden breaking and slipping of one part past another, but by *flowing* quietly and without shock to its new position. In their movements deeply buried rocks obey the laws of hydrostatics, not the laws of solid bodies. Under the great weight from above the rocks yield and flow, and adjust themselves under lateral pressure like tallow or wax. Rocks under these conditions are in the *zone of flowage.*

It is to be expected, of course, that rocks of different character will behave differently in the zone of flowage as well as in the zone of fracture. A strong, thick stratum will flow with less ease than a thin, weak bed; and a stratum which is protected by strong beds above and below will act very differently from one not so situated. This conception of the complete plasticity even of the firmest and most resistant rocks, when deep-seated and subjected to pressure from the sides, is essential if one is to understand metamorphic rocks. Minute plications, and structures showing mashing, welding, and other evidences of adjustment by flowage, are characteristic of the Connecticut metamorphics. These structures can be seen from one end of the state to the other, when a ledge as a whole is looked at, when a hand specimen is examined, or when a thin section is viewed under the microscope. The perfection of structure of this type is remarkable. As is shown in Plate IX, Fig. 1, the minute particles of mica and other minerals form a stream which takes a general direction, but, like a stream of water, bends or divides to adjust itself to the obstructions in its path. The simile of the stream must not be understood to

PLATE IX.

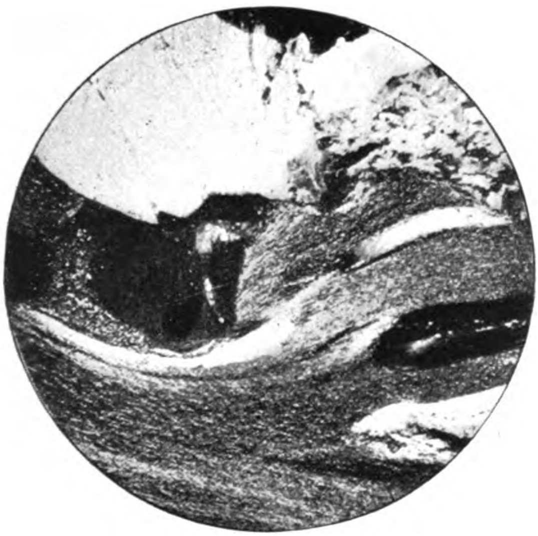


FIG. 1. MICROSCOPIC SECTION OF CRUSHED QUARTZ PORPHYRY, SHOWING ADJUSTMENT OF MINERAL PARTICLES BY FLOWAGE.

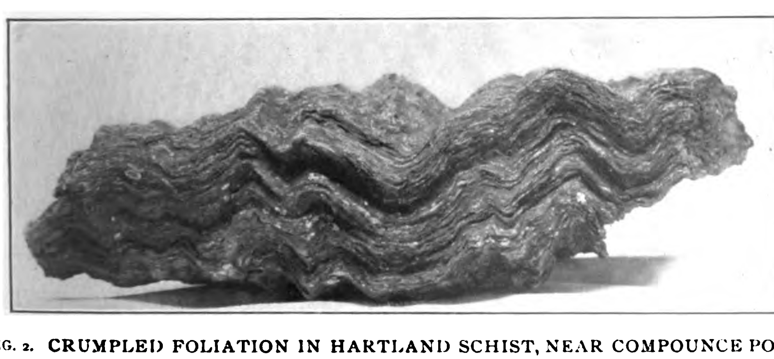


FIG. 2. CRUMPLED FOLIATION IN HARTLAND SCHIST, NEAR COMPOUNCE POND.

imply that the particles have reached their position by moving continuously in one direction, for adjustments have taken place wherever the pressure has permitted. The minute flakes of mica form parallel bands which wind in and out around the harder kernels, along lines of dragging or squeezing, thus allowing the rock to flow.

The rocks shown in Plates IX and XII, though now exhibited at the surface of the earth, are believed to have been formed in the zone of flowage, some miles below the surface, and will serve as illustrations of schists and gneisses so common within the state, which are believed to have been formed within this same zone. If these views are true, they give some clew to the amount of erosion which has taken place throughout southern New England. (See page 28.) Miles of strata must have been removed to expose these rocks formed in the zone of flowage.

The Zone of Fracture and Flowage.— Because rocks are not uniformly strong, and because they may be subjected to different conditions of pressure, it will be readily understood that some strata may be in the zone of flowage, while others, buried to the same depth, may be in the zone of fracture. At a given depth weak rock would adjust itself by flowing, while stronger rock would break; for example, a bed of shale may be in a state of plasticity when much nearer the surface than a bed of firmly cemented sandstone. Certain beds may be completely metamorphosed, while adjoining beds retain much of their original character.

In trying to unravel the tangle of metamorphic crystalline rocks, search is made in the field for the more recent beds, in the hope that some structures may have outlasted the changes that have occurred. Part of a rock may be in the zone of fracture, while other parts of the same rock yield by plastic flow. Certain formations occurring in Connecticut, as the Brimfield schist, show little fracture, and yet the microscope reveals the fact that individual grains of quartz have been broken and recemented. The rock has

been plastic and has yielded without breaking, or has broken, in accordance with its position and the nature of the stress applied. The structures of such rocks were developed in the *zone of combined fracture and flowage.*

The Three Zones Compared.— In order to understand the relation of these three zones we may assume, as suggested by Van Hise, an imaginary homogeneous rock extending from the surface to an indefinite depth. When such a rock mass is subjected to lateral pressure, the parts near the surface will be broken into blocks by faults and joints. Here the individual particles composing the rock are little affected except immediately along the joints, and the texture of the rock and its fossil contents are little modified. Farther below the surface, the lines of fracture become closer together, and the blocks are reduced to slabs and then to thin layers. Deeper down every particle of rock takes part in the deformation. The rock is granulated and partially recrystallized. Still farther down recrystallization becomes the dominant process, and the rock loses its former nature entirely and becomes metamorphosed. It may then be classed as a crystalline schist. There is, of course, every gradation from one of these stages to another. A case is described from the Coast Range of California, where there "are seen all stages of transition between brecciated igneous rock and a crystalline schist." "In passing from the breccia to the schist, one first finds, about the blocks of igneous rock which have their characteristic textures, mere films of schists. Passing farther toward the schist, an intermediate stage is found, in which unmashed blocks lie in a schistose background or matrix. But a short distance from this place is the completely altered schist, in which no unmashed fragments remain." * The same phenomena may be observed in the Appalachian districts of Tennessee. Many of the Connecticut crystallines were formed in this zone of fracture and flowage, or through

* Van Hise, in *Bull. Geological Society of America*, vol. IX, p. 313.

erosion have been brought to this zone from that of flowage. They exhibit fracturing and folding both on a large scale and microscopically. Unfortunately no localities have been found where it is possible to trace these schists through the different stages, from their original unaltered state to their present crystalline form.

STRUCTURE OF METAMORPHIC ROCKS.

The metamorphic crystalline rocks of Connecticut exhibit structures very unlike the sedimentary strata of the central belt. They are everywhere seen to be in layers, usually very thin, and to present a banded appearance. When seen from above, the ledge appears to be traversed by innumerable lines, which are the edges of planes along which the rock may be divided into a multitude of slabs or sheets. When viewed from the side, as in railroad cuts (for example, along the line of the Highland Division or the Central New England Railroad), the sheets seem to be inclined at a high angle, usually nearly vertical. Thus, rocks produced by regional metamorphism have the appearance of being sedimentary beds that have been deposited in a horizontal position and then turned up on end by some movement within the earth's crust. There is one striking difference, however, between these layers and sedimentary beds: namely, the metamorphic rocks are composed of more or less complete *crystals,* close pressed and interlocking, instead of worn *fragments* of material cemented into solid rock. Furthermore, this division into planes, or apparent bedding of the crystallines, does not indicate that the rock was deposited in layers; but it is a new structure which has been developed in the rock by the process of metamorphism. So far as the writer has observed, there is not within the state a metamorphic rock whose present division into sheets is perfectly coincident with the structure of the original unmetamorphosed sediment.

In order to understand this difference between real and apparent bedding, it is necessary to examine the princi-

pal structures found in metamorphic rocks, and also to consider their mode of development. One of the characteristic properties of a metamorphic rock is its capacity to break more easily in certain directions than in others. This property is called *cleavage*. The same name is applied to a property shown in minerals. For instance, when calcite is broken, the fragments are not irregular and without definite form, but are rhombohedrons, and their shape is determined by the position of the cleavage planes in this particular mineral. When a metamorphic rock is broken, it is seen to part easily along certain lines and with difficulty along others. Yet the use of the same name should not lead to a confusion of the two phenomena. Minerals cleave because of a definite arrangement of their molecules; rocks cleave because of the parallel arrangement of their constituent minerals.

When, as a result of cleavage, a rock has the capacity to separate into parallel layers, or laminæ, it is said to possess *slatiness, foliation,* or *schistosity*. A *slate* is a crystalline rock which has the property of cleavage and separates into layers with relatively smooth surfaces. A *schist* also has the property of cleavage, but the surfaces separating the laminæ are usually more or less rough. In the slate the component crystals are of small size — even microscopic; in the schist the mineral particles are larger. Slatiness and schistosity are thus seen to have essential characters in common, and there is every gradation between the two.

A word may be added here to call attention to the confusion existing in the use of the words *slate* and *shale*. Both of these rocks break into thin layers with quite even surfaces, and hand specimens of the two appear superficially much alike. Their texture, origin, and history, however, are widely different. Shale was formerly mud deposited by water, and is composed of fine broken particles cemented together. It has never been deeply buried nor subjected to great heat and pressure. The laminæ of which it is composed are of the same thickness and made of the same ma-

terials as when first deposited by the quiet water. Slate, on the other hand, owes its texture, structure, and composition to heat and pressure. It is metamorphic, not sedimentary. It is composed of crystals, not of broken fragments. Its laminæ are due to movement under pressure, not to its method of deposition by water. Slate may be made from shale or from other rock. Slatiness may be developed while there still remain traces of the material and structure of the original rock. There is no slate in Connecticut within the Triassic area, but brown and black shales are abundant. No shales are found in the crystallines, but slates are developed in several places.

Origin of Schistosity.— We may now inquire briefly how schistosity and slatiness are brought about. In the first place, it is to be remembered that these phenomena are produced only in the zone of flowage, where crevices cannot exist. No opportunity is there offered for surface changes, and little or no chance for foreign matter to be brought in, so that the great alteration which occurs must be due to chemical reaction. The rock is subjected to heat and pressure in such a manner that part after part passes into solution, and incessant changes of position are taking place. In this way the material can adjust itself to the changing form of the rock mass. In this connection the importance of the small amount of water contained in the rock is very great, as it aids in dissolving old crystals and in recrystallizing the amorphous material. Schistose rocks are composed of innumerable particles having the longest diameters or easiest cleavage or both in a common direction. The minerals are for the most part made from the materials in the original rock, and the new minerals are flattened by great pressure and forced into parallelism. Some of the original flat minerals are also rotated into parallel position. The net result is that most of the minerals have a parallel arrangement, and the rock accordingly splits along these cleavage planes more readily than in other directions. The most important of the minerals that fall into

parallel position are the micas. The next in importance are feldspar, amphibole, and chlorite. Rocks containing abundant mica — i. e., mica schists — make up a large part of the crystalline areas of Connecticut; and wherever schistosity is well developed, crystals of muscovite and biotite are large and closely parallel in position.

The process by which new materials form by recrystallization may be illustrated by the micas. Muscovite and biotite are comparatively rare in the sediments which are most readily transformed into mica schist. For instance, there may have been no mica whatever in the shales and sandstones from which the Hoosac and Bolton schists developed, and yet at the present time mica is a characteristic part of these metamorphic rocks. Soils, clays, and shales contain elements from which mica may develop. Some of the necessary constituents are found in feldspar, and some in various hydrous minerals, as kaolinite, chlorite, limonite, etc., and these minerals are commonly present in the rocks from which mica schist develops. The schist itself, however, may be entirely free from such minerals. During the process of metamorphism the hydrated minerals have been taken into solution, and from this solution the mica crystals have been developed, and the material has been thus rendered more compact. When the little crystalline grains of mica begin to form, their position is controlled by the pressure to which the rock is subjected; hence, as more and more material is deposited to complete their crystalline outlines, the micas form in parallel position. Micas are thus seen to be a continuous growth by recrystallization during the process of metamorphism. But it seems essential that the chemical process be controlled by dynamic action.

The schistosity which characterizes Connecticut crystallines is due to chemical action carried on in the zone of flowage under mechanical pressure, and is an entirely new structure, bearing no definite relation to that present in the original rock.

Throughout Connecticut the planes of schistosity are, roughly speaking, north-south to northeast-southwest, and

the lateral pressure in the earth's crust must have come from the southeast. The planes of schistosity dip generally to the southeast, so that the tops of the metamorphic layers have been pushed to the northwest or their bottoms to the southeast. There are, however, many local variations; and this simplicity of structure is interrupted by the presence of intrusive masses of diorite, granite, and other igneous rocks, about which the schistose planes seem to wrap. In such cases the direction and dip of the schistose layers assume various attitudes. For instance, at Bristol, the planes of schistosity lie in nearly every direction of the compass in order to adjust themselves to the rounded mass of granite-gneiss which underlies the city.

Fissility.— The surfaces of parting which constitute the cleavage planes in a rock may be present without being apparent to the eye. Weathering, however, often serves to bring the planes of separation into prominence, and to convert them into definite cracks. Such open cracks, as described below, may by subsequent changes be recemented.

Strictly speaking, when rocks are actually parted, instead of possessing merely the capacity to part, they are said to be *fissile* or to possess *fissility;* and many of the Connecticut schists may be thus characterized.*

When for any reason a parting of the rock takes place along planes of schistosity, an additional factor enters to complicate the structure. In the crevices between the laminæ new mineral substances may be deposited by water or injected from an igneous mass so as to fill the space completely. The result is a banded rock which has the appearance of a true metamorphic gneiss or schist, but which has been developed in a different way. These seams of infiltrated or injected rock may be of unlike substances and vary from mere films to layers an inch or more in thickness. In

* While cleavage planes may, as above explained, be converted into open cracks by subsequent changes, when the rocks are brought nearer to the surface by erosion, it is also true that, if the rocks at the time they are subjected to pressure are in the zone of fracture instead of being in the zone of flowage, the structure produced by pressure will be fissility instead of cleavage.

some cases these seams are really small dikes, and are offshoots from some granite mass in the neighborhood. Commonly they are lenses or films of infiltrated matter, approaching the character of true veins. In either case the structure may be so delicately formed as to follow the most minute plications in the original rock. Care must be taken not to confuse such injections or infiltrations with metamorphic laminæ produced by lateral pressure.

Joints and Faults.— Fissile rocks have abundant partings running in the direction of schistosity, which are to be considered as open cleavage cracks. The planes of cleavage were originally produced by pressure at right angles to their present alignment, and the fissility resulted from the opening of cracks by release of pressure and weathering or from other causes. The schistose and slaty rocks are quite commonly fissile, especially when exposed for some time to surface agencies. But the rocks may also show divisional planes in other directions than that of the cleavage.

Joints are the ordinary cracks seen in ledges. Very rarely, indeed, are they absent from rocks exposed at the surface. Commonly there are two or more sets, the two most prominent sets being often roughly at right angles to each other. The rock surface may be thus divided into polygonal areas. In regions like Connecticut, where the rocks have been intensely metamorphosed and have experienced many movements and much disturbance, the joints are very numerous and prominent, and run in many directions. All planes of actual separation in rocks, whether of fissility or of jointing, are produced near the earth's surface and not at great depths, and are the results either of compression or of tension in rocks. The openings are usually regarded as results of tension.*

When movement has taken place along a joint plane or

* For a full discussion of the joint and fault system of Connecticut with its resulting effects on topography, see the writings of W. H. Hobbs, especially the following:— *Newark System of Pomperaug Valley* (*U. S. Geological Survey, Twenty-first Annual Report*, Pt. III); *Geological Structure of South Western New England* (*Am. Journal of Science*, series 4, vol. XV, pp. 432-449); *River System of Connecticut* (*Journal of Geology*, vol. IX, pp. 469-485).

plane of fissility, so that the rocks on one side are depressed or elevated in respect to those on the opposite side, the displacement constitutes a *fault*. Because of similarity of material on two sides of the fault plane, such structures are rarely noticeable in the crystallines. In some cuts, however, the crumbled rock shows plainly that a movement has occurred; and smoothed surfaces, known as "slickensides", and indicating slipping along joints, are visible in nearly every quarry in the state. The igneous and sedimentary rocks of the Triassic formation are much better suited to exhibit fault structures than are the ancient crystallines. In metamorphic rocks, however, there is abundant evidence that faulting has taken place. Cliffs occur which seem to owe their position to faulting, abrupt changes are noted in the direction of boundary lines of certain formations, and crushed rock and slickensides are found along the lines of breaking.*

MINERALS IN METAMORPHIC ROCKS.

In this chapter it is not intended to describe the rock-making minerals, but a brief explanation of those most commonly met with in Connecticut, which owe their existence and form to metamorphism, may be found helpful to the reader who is not a student of mineralogy.

The various forms of quartz found in metamorphic rocks differ in no essential particulars from quartz found in sedimentary rocks, except that complete or broken crystals occur instead of rounded grains. The quartz is either original, or has been produced by metamorphism of feldspar.

Feldspar is the most abundant constituent of crystalline rocks; and, for that matter, the most abundant mineral found at the earth's surface. It has many species and varieties, which are complex chemical compounds; and when a rock containing this mineral suffers alteration numerous changes take place. Feldspar may alter into quartz and muscovite. In this case the muscovite commonly occurs as

* See page 200, for a discussion of faults in the Triassic area.

minute flakes which form a sort of film over the rock surface along planes of foliation, as in the schist at Compounce Pond and in Tolland. Feldspar alone may change to quartz and muscovite. With the addition of magnesium and iron, feldspar may change to quartz and biotite, or to quartz and chlorite. In other cases quartz and epidote result. Thus it appears that, when muscovite or biotite or quartz appears in metamorphic rocks, it may be an entirely new mineral, and have been represented in the original rock by feldspar.

Hornblende alters to biotite or to chlorite, and from this to zoisite or epidote.

Angite commonly alters to hornblende, and then to chlorite, biotite, etc.; or changes directly into these minerals without passing through the hornblende stage.

Biotite and muscovite of sedimentary and igneous rocks are usually unchanged by metamorphic action; but the great abundance of these minerals in schists and gneisses is not due to their presence in the unchanged rock mass, but to the fact that they are so readily produced from other minerals, as shown above.

The calcium carbonate of metamorphic rocks is crystalline in texture, and may occur as calcite, or part of the calcium may be replaced by magnesium and dolomite be produced. The calcareous rocks of the Canaan and New Milford districts are dolomitic. Properly speaking, this rock, of which the State Capitol is built, is a dolomitic *marble*. The original limestone has suffered metamorphism which caused the entire mass to be crystallized. A common alteration of dolomite is into tremolite, a variety of amphibole. Tremolite crystals frequently occur in the dolomitic marble of Connecticut; and in places, *e. g.*, the camp-meeting ground near Canaan, they weather out of the marble and may be gathered in large numbers.* Hornblende also results from alteration of dolomite, and some of the black hornblendic bands occurring in the crystallines may be the pres-

* The crystals at this locality have the form of pyroxene, though they have assumed in greater or less degree the cleavage structure of amphibole. They seem to have been first formed as crystals of diopside, and then undergone a change of molecular arrangement converting them into tremolite.

PLATE X.

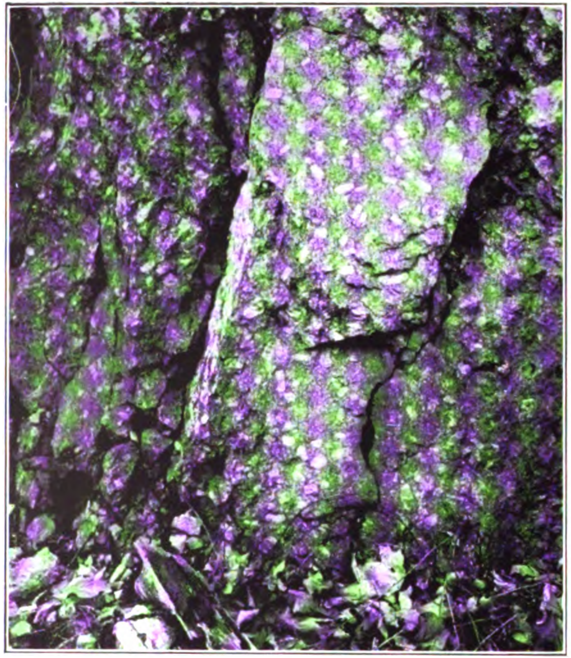


Fig. 1. PORPHYRITIC TEXTURE IN GRANITE-GNEISS, DERBY.

The phenocrysts are feldspar.

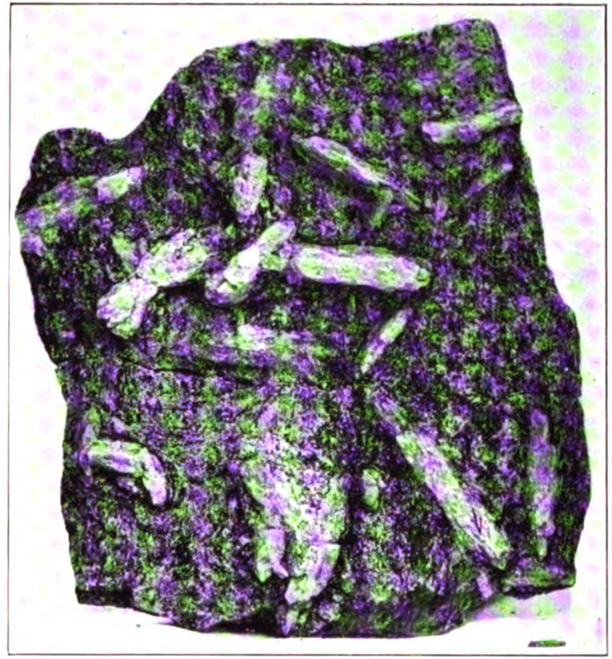


Fig. 2. PORPHYRITIC TEXTURE IN SCHIST, DEVELOPED FROM SEDIMENTARY ROCK, WEST STAFFORD.

The phenocrysts have been brought into prominence by weathering.

ent representatives of original limestones which became marble and then hornblende schist and gneiss. The change from marble to hornblendic rock is a complex process, and involves the addition of silicon, aluminum, iron, and magnesium.

In addition to the minerals which occur commonly in sedimentary, igneous, and metamorphic rocks alike, there are a number that assume a prominent rôle in metamorphic rocks alone. Those most abundant in Connecticut are: garnet, cyanite, andalusite, staurolite, fibrolite or sillimanite, chlorite, serpentine, and epidote.*

Porphyritic Textures.— For the most part metamorphic rocks are made up of crystalline grains which differ little among themselves in size, none of them being large. Certain of the schists and gneisses, however, exhibit a marked variation from this structure. In these rocks one or more minerals have crystallized on a much larger scale than the others, and the rock appears as a mass of medium-sized crystals, among which large ones are scattered. The larger crystals, called *phenocrysts* (*i. e.*, easily seen crystals), may be hundreds of times larger than those in the ground-mass, and may be several inches in diameter. In Connecticut, the more important minerals that show themselves as phenocrysts are feldspar, garnet, staurolite, cyanite, and hornblende. The structure is well seen in the Prospect gneiss and in the Bolton and Hartland schists (see Plate X).

The phenocrysts of the porphyritic gneisses and schists usually have well defined crystal outlines, showing little evidence of pressure, and must have been developed after the date of severe metamorphism. Furthermore, the crystals are not always arranged in accordance with the planes of schistosity, but seem, in part, at least, to have developed after the structure was formed. In case the phenocrysts developed at a later date than the development of the schistosity, they seem to be the result of absorption and en-

* For a description of these minerals the reader is referred to standard treatises on mineralogy, and particularly to E. S. Dana's works: *Minerals and How to Study them; Text-Book of Mineralogy; System of Mineralogy.*

largement of crystals during the period of relative quiet which followed the great dynamic forces that produced metamorphism. Great heat and moisture in the rocks would be necessary conditions. In those cases in which further metamorphic change has occurred after the formation of the phenocrysts, the crystals are seen to have been drawn out along the planes of schistosity, and often to have assumed a lenticular shape, and to have had their ends drawn out into lines of broken fragments. This is well shown in the porphyritic gneiss about Derby.

Many phenocrysts in gneisses, however, are older than the structures produced by metamorphism. Porphyritic structures belong also to igneous rocks; and many porphyritic gneisses are igneous rocks which have been metamorphosed, but not to an extent sufficient to destroy the original porphyritic structure. A porphyritic gneiss developed from an igneous rock with porphyritic texture thus has a life history made of a number of stages. In the original molten mass (magma) large distinct crystals formed, which floated in the remaining liquid material. A change then took place which caused the rest of the mass to solidify more quickly and therefore to form small crystals. The rock may have remained for some time as an igneous porphyry, but was finally squeezed and stretched by the forces which converted it into a porphyritic metamorphic rock. Thus the rock reveals within itself much of its history.

SOME OF THE PRINCIPAL METAMORPHIC ROCKS.

The theoretical principles briefly treated above may perhaps be better understood by noting the characteristics of the principal kinds of metamorphic rocks and their stages of development from unaltered sedimentary or igneous rocks to their present state. The types represented in Connecticut are marble, quartzite, slate, schist, and gneiss. The last two rocks are the most widespread in the state, and, in fact, make up a large part of the floor of New England.

Marble is metamorphosed limestone, and the change occurs usually where there has been great pressure and strong dynamic action. The chief mineral constituent of limestone is calcite, but the calcium may be partly replaced by magnesium, forming dolomite. Metamorphism results in a complete crystallization of the grains of calcite and dolomite, and the production of a rock which is a mass of calcite and dolomite crystals. Marble rarely develops a schistose structure or slatiness. It is so soft and so readily taken into solution that the grains in the original limestone have adjusted themselves by recrystallization and by moving along cleavage planes. The Stockbridge limestone (see page 87) is dolomitic, and, though closely folded in with schists, shows little schistose structure. Limestone is no exception to the rule that sedimentary rocks contain impurities. From these impurities metamorphism develops minerals which commonly occur in marbles. Garnets are found, also pyrite and other iron compounds; micas may show abundant development; pyroxene and various varieties of amphibole, especially actinolite and tremolite, also occur. Impure limestone in certain localities has been altered to hornblende schist or gneiss, and calcareous hornblendic bands occur in connection with the other crystalline rocks of the state. So far as known, the Connecticut marble is all dolomitic, and it varies much in the degree of its purity. The rock quarried in Canaan is perhaps the best obtainable, but its impurities are points of weakness.

Quartzite is a metamorphic sandstone. In the original sandstone rounded grains of quartz are held together by a cement which is commonly silica, iron oxide, or calcium carbonate. In the process of metamorphism parts of the quartz grains are dissolved, and the silica is redeposited in the spaces between the grains, or is added to the grains in such a manner as to produce the crystalline form peculiar to quartz. The sandstone is thus so thoroughly indurated that, when broken, the fracture passes more readily through the original grains than through the cement. There are, of

course, all stages of metamorphism, from hardened sandstone to quartzite so vitreous as to be scarcely distinguished from the quartz occurring in veins. The amount of silica required to convert sandstone into quartzite has been estimated at one-third to one-sixth the amount of the original grains. Where quartzite is a widespread formation, the amount of new material which owes its existence to metamorphism is therefore enormous.

The formation of quartzite by "cementation," as indicated above, does not require deep burial, nor pressure sufficient to produce schistose structure. When, however, quartzite is buried so deeply as to reach the zone of flowage, and is subjected to mashing by lateral thrust, schistosity is developed, and the rock is traversed by planes of cleavage, and passes into a schistose quartzite and finally into a *quartz schist.* In the first stages of the process the quartz grains are flattened and somewhat rearranged, lines of fracture appear, and finally the quartz loses its crystalline orientation and becomes a mass of broken grains. This formation of small fragments of quartz from crystals takes place most readily when little or no water is present in the rocks. Simultaneously with this granulation process new quartz and perhaps mica may develop in the spaces between the grains, from the impurities in the original sandstone. The result is that films of mica and occasionally other minerals form along the planes of foliation, and the schistose structure is complete.

Neither quartzite nor quartz schist is abundant in Connecticut. It caps Great Hill near Cobalt, where it is much like the numerous occurrences of quartz veins in the state. The exposures on Sharon Mountain and Cream Hill are of a massive granular rock, largely composed of quartz and feldspar. Areas of quartz schist occur in Tolland, Woodstock, Plainfield, Thompson, south of Bantam Lake in Morris, and small bands of the rock in a few other localities. The rock from Bolton was formerly quarried for flagstones, and glistening blocks from this locality may be seen in the

streets of our large cities. Quartz schist is suitable for whetstones, and was formerly quarried for this purpose at points in the eastern part of the state.

Slate is the metamorphosed equivalent of shales, or fine-grained clay rocks, which, in turn, are consolidated muds of various sorts. The chief constituents of clays and shales and other argillaceous rocks (besides a variable amount of kaolinite) are quartz and feldspar. In passing to a metamorphic stage the quartz fragments may remain as such, or they may be recrystallized, thus losing all trace of their origin. The feldspar alters to quartz and mica, and single feldspar fragments may be changed into a great number of crystals of quartz, mica, and feldspar. The fine quartz of slate is thus seen to be not the same as the original quartz grains in the mud or shale from which the slate developed. As in all cases of dynamic metamorphism, the mica crystals are developed in parallel position with long axes and cleavage in a common direction. It is due to this fact that slate splits so evenly. The mica crystals are usually too minute to be readily observed without a microscope, and are so massed as to produce merely a smooth surface. As might be expected, muds and shales are not made of pure quartz and feldspar, but contain many impurities; and, accordingly, many slates contain minerals like pyrite, etc., and only in exceptional places is the quality of the rock such as to render it commercially valuable. When a slate is further metamorphosed, but not to a point at which large crystals of mica are developed, it is termed *phyllite*. Such is the rock exposed in parts of Pomfret and along the shore at Woodmont.

Extreme metamorphism produces mica schist from slate and phyllite, and most of the Connecticut slate has reached that stage.

Schist.— Schists and gneisses are the two great classes of rocks produced by widespread, profound metamorphism. Practically all the crystallines of Connecticut fall into these groups. *Schist* is a term used to indicate structure, not

composition. The word implies nothing as to the minerals which compose a rock, but means that it has schistosity, and breaks readily and with a wavy surface along planes of foliation. Schists represent the extreme of metamorphic action, and may be derived from almost any sedimentary or igneous rock, or from almost any other metamorphic rock except marble.

Mica schist is a widespread formation in Connecticut, and is ordinarily developed from shale, sandstone, or conglomerate. As in the formation of quartz schist, mentioned above (page 62), the enormous pressure and heat of the zone of flowage granulates the quartz, and breaks up the feldspar into quartz and mica and other feldspar. Much mica is thus produced, and the mica increases in amount as the mashing and fracturing are more severe. Thus mica schist is a rock of schistose structure composed essentially of quartz, feldspar, and mica. While mica is not the most abundant of the three minerals, yet the size of its crystals and the fact that it forms a coat over the different layers make it the most conspicuous constituent. The feldspar present is usually albite, instead of the orthoclase which is more abundant in the original sediment. There are all stages in the formation of mica schist. Mica may be sparingly developed, and the original grains of the sandstone may play an important rôle; again, the rock may be in part slate and in part mica schist, or layers of schist may alternate with layers of altered sandstone; again, the rock may be typical mica schist with no trace of its former character. Most of the Connecticut mica schists have reached this advanced stage, and only rarely do structures occur which indicate the original form and composition. The size of the mica flakes or crystals varies from minute particles of muscovite, which form a coating over the schist plane, to large flakes an inch or more in diameter. Generally speaking, the larger the flakes the more severe the metamorphism. Mica schist rarely exhibits uniform parallel foliation, but irregular, wavy, and crumpled structures (See Pl. IX, Fig. 2). Moreover, a

mica schist formation may show great variety in composition; calcareous, argillaceous, ferruginous, and silicious beds may alternate or may form irregular inter-dovetailing lenses.

Because of the impurities in the original rock, mica schists often contain abundant minerals other than the main constituents. Garnet, fibrolite, cyanite, and staurolite occur in such quantities in the Connecticut schists that locally the rocks might be properly called garnet mica schist, cyanite mica schist, etc. In most cases, however, the development of such minerals on a large scale is local, and represents local variation in the composition of the original sediment. Mica schist which is slightly graphitic from the presence of organic material in the sediment also occurs in Connecticut.

Hornblende schist occurs in this state usually in belts interlaminated with mica schist or gneiss. It is greenish black in color, and consists of hornblende together with quartz, feldspar, biotite, and other minerals in smaller amount. Such a schist may result from the metamorphism of an impure dolomite, but is to be traced more commonly to some basic igneous rock, especially if the schist is quite free from minor impurities. One of the most common things in the rock floor of Connecticut is to find lenses, layers, streaks, and dikes of hornblende schist distributed without any apparent order within the larger areas of metamorphic rocks. In general they are ascribed to igneous intrusions at a date simultaneous with or prior to the last period of intense metamorphism.

Gneiss is a term used to designate a rock which possesses schistosity, but does not cleave into such thin laminæ, nor with such wavy, crumpled surfaces as schist. The amount of mica is proportionally smaller, and the quantity of feldspar is much greater than in schists. Gneiss appears as a much more massive rock than schist, and the layers into which it may be separated with ease are much thicker and

more uniform in character. The gneissoid structure, however, is produced in the zone of flowage in a manner identical with the schistose, and there is every gradation between schists and gneisses, as there is between gneisses and the unaltered rocks from which they may develop. Thus we may have schistose gneiss and gneissoid schist. Gneisses, like schists, receive special names from their characteristic mineral — mica gneiss, hornblende gneiss, etc.; or are named for the rock of which they are the metamorphosed equivalents — granite gneiss, diorite gneiss, etc.

Gneisses originally were sediments (sandstones and conglomerates), or igneous rocks of various types. In passing from a coarse sandstone to a mica gneiss, the individual quartz grains are destroyed, as is explained above under mica schist (page 64), and new quartz crystals are made. Feldspar breaks up into quartz, feldspar, and mica, and the impurities present form less abundant minerals. The larger pebbles in the sandstone are of course flattened and crushed; and, if metamorphism has not proceeded too far, remnants of the pebbles remain to tell the story of the origin of the gneiss. The gneisses of Connecticut have gone far beyond that point in development, and no traces of original pebbles have been observed.

The gneisses which originate from igneous rocks are much more common, and form larger areas. Here the process of metamorphism is chiefly one of rearrangement of mineral particles; the micas are drawn out into parallelism, as are also the other minerals; and new flattened micas are produced from feldspar. If the original rock was of simple composition, the gneiss will have practically the same mineral composition, the only noticeable difference being a greater abundance of mica, both muscovite and biotite. In case the igneous rock was porphyritic, the gneiss will also exhibit that texture, provided metamorphism has not advanced so far as completely to crush the phenocrysts. In such cases a gneiss produced from sedimentary conglomer-

PLATE XI.

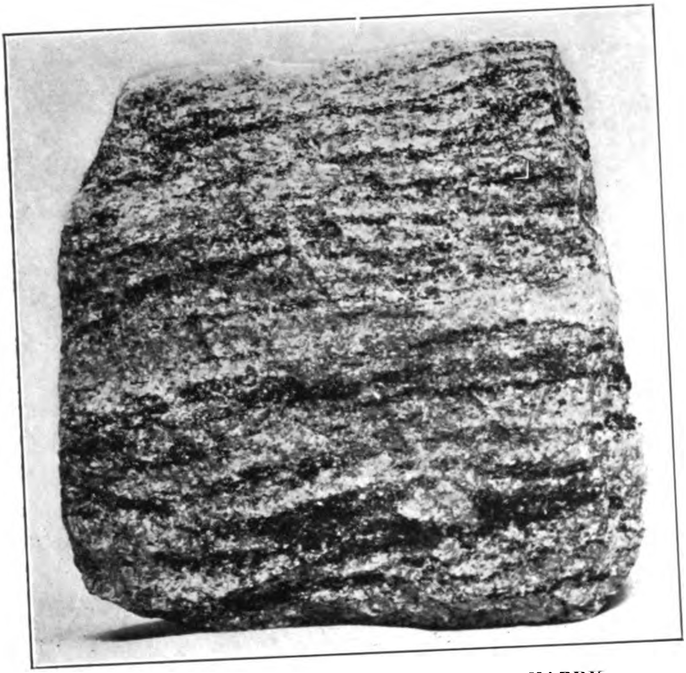


FIG. 1. GNEISS FROM LEETE'S ISLAND QUARRY,
Showing gneissoid structure due to squeezing and stretching of granite.

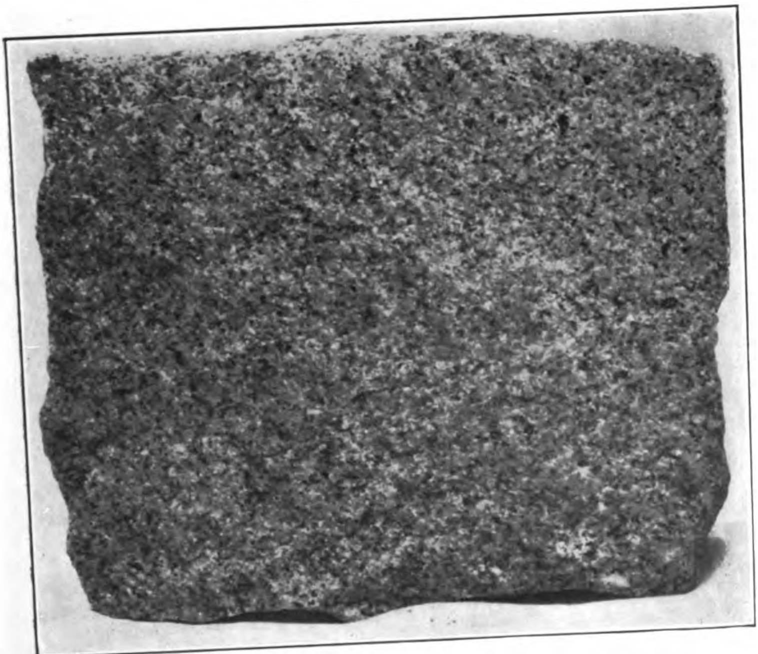


FIG. 2. GRANITE FROM BOOTH'S QUARRY, WATERFORD.
Showing granite structure.

ates resembles superficially one produced from porphyritic granite (see Plate X).

The common types of gneiss in Connecticut are mica or granite gneiss,* and hornblende or diorite gneiss. The mica gneisses are ordinarily squeezed, mashed, and drawn out modifications of granite and related igneous types. Plate XI shows the contrast in structure between the gneiss and the unaltered granite. The production of gneiss is facilitated if granite intrusions occur in the region and thus furnish feldspar to be added to the rock during the process of alteration. The hot mass promotes the formation of solutions that carry abundant feldspathic material out of which feldspar can be made. Much of the beautiful banding in gneiss is produced, not by the common process of development of minerals under pressure, but by the intrusion of foreign material along the planes of schistosity, as is explained on pages 55 and 69. An outcrop of ordinary granite gneiss exhibits bands of granitic material separated by thin micaceous bands; but certain granite gneisses have, in addition to the foliation structure effected in the zone of flowage, a series of bands composed of light or dark colored rock which were originally no part of the constituents.

It ought, perhaps, to be stated that earlier geologists did not accept the theory here presented that gneisses are ordinarily squeezed and stretched granites. Gneiss was considered as modified sedimentary rock, and the gneissoid structure was believed to be equivalent to the planes of stratification in the original sediments. Furthermore, even granite areas were looked upon by some geologists as altered gneisses; that is, granites were supposed to have come from gneisses, and not gneisses from granites. Some gneisses are metamorphosed sedimentaries, most of them are altered igneous rocks, and no case is known where granites have originated from gneisses.

* This phrase, as used here, and as used by many writers, signifies a gneiss whose mineralogical composition is the same as that of granite, without regard to its origin. In Part II of this chapter the name "granite-gneiss" is applied to gneisses which are believed to be derived from granites.

Hornblende gneiss may develop, like hornblende schist, from impure limestone, but commonly represents a dark colored igneous rock, diorite, diabase, or some similar type. When in large masses, hornblende gneiss has a tendency to split into slabs with fairly smooth parallel faces.

Gneisses are not distinguished commercially from granites. Thus, the Monson "granite" and the Becket "granite", which are freely used in Connecticut buildings, are gneisses, as is the Glastonbury "granite", used for curbing in Hartford. The rock quarried along the Connecticut, from Middletown southward, and sold as granite, is likewise usually granite-gneiss. Parts of the Bristol and Collinsville "granites" are used for building, but much of the rock quarried comes from dark bands and lenses in a granite-gneiss formation, and is properly diorite-gneiss.

Igneous and Sedimentary Gneisses and Schists.— It has doubtless become evident to the reader that there is every gradation between the various gneisses and between the various schists, as well as between gneiss and schist, and unfortunately it often happens that these gradations occur in a single locality, and it is impossible to discriminate types and classify the rocks except in an arbitrary fashion. The difficulty is still greater when one attempts to trace the history of these rocks and to determine their original character. After a rock has become a gneiss or a schist, how is it possible to decide whether it was originally sedimentary or igneous, and what, therefore, was the condition of the country during the time of its formation? If any structures indicating deposition or any unchanged fragments of pebbles, etc., exist, then the sedimentary character is proved; but even here great care must be taken to distinguish between the structure of a crushed conglomerate and the structure produced in a rock which was metamorphosed, then injected with foreign material, and then crushed in a second metamorphism. When, however, all original structures are destroyed, and no localities can be found where

completely metamorphosed rock may be traced to less altered rock retaining some of the original character, no positive statement may be made. There is, however, one highly probable suggestion regarding such rocks. From their nature igneous rocks have a certain tendency toward uniform texture and composition, and freedom from important structure lines. When mashed by extreme metamorphism, they therefore tend to produce uniformly foliated, homogeneous schists and gneisses. Sedimentary strata, on the other hand, exhibit wide variations within a small space, and possess prominent structure lines. Their composition is variable, and an analysis of a sedimentary rock would be of very local application. A metamorphosed sediment is more apt to be heterogeneous, and to exhibit more marked banding and crumpling, and much greater variety of mineral constituents. However, this criterion must be applied with caution, and it is to be kept clearly in mind that some of the schists and gneisses of the state hold the secret of their origin fast; and, although we believe the rocks contain a record of their life within themselves, yet science has not advanced to a stage in which the symbols can always be deciphered.

Banding in Gneisses.— The structures which characterize gneisses have been brought about, as we have seen before, largely by pressure; and the difference in the appearance of the laminæ is due mainly to the greater or less amount of new mineral produced by metamorphic action. In this way the gneisses have assumed the banded or ribboned structure which may be scarcely noticeable or very conspicuous, depending upon contrasts in color and texture between the bands. There are, however, other ways in which this banded structure may be effected. In the cracks between the laminæ new minerals may be deposited from water solution, or the cracks may be filled by molten rock forced in from below. In this manner a banded structure would be produced that would closely resemble the structures due to lateral pressure. Furthermore, banding thus produced would bear much resemblance to original bedding

in sedimentary rocks, and must be carefully distinguished from it. When a rock mass is fissile, there is an excellent opportunity for the injection of igneous matter or for the introduction of material in solution; and, when the cracks are thus filled, the entire rock mass is firmly cemented together. Such a rock will have cleavage, but may show no evidence that it was once separated into distinct laminæ.

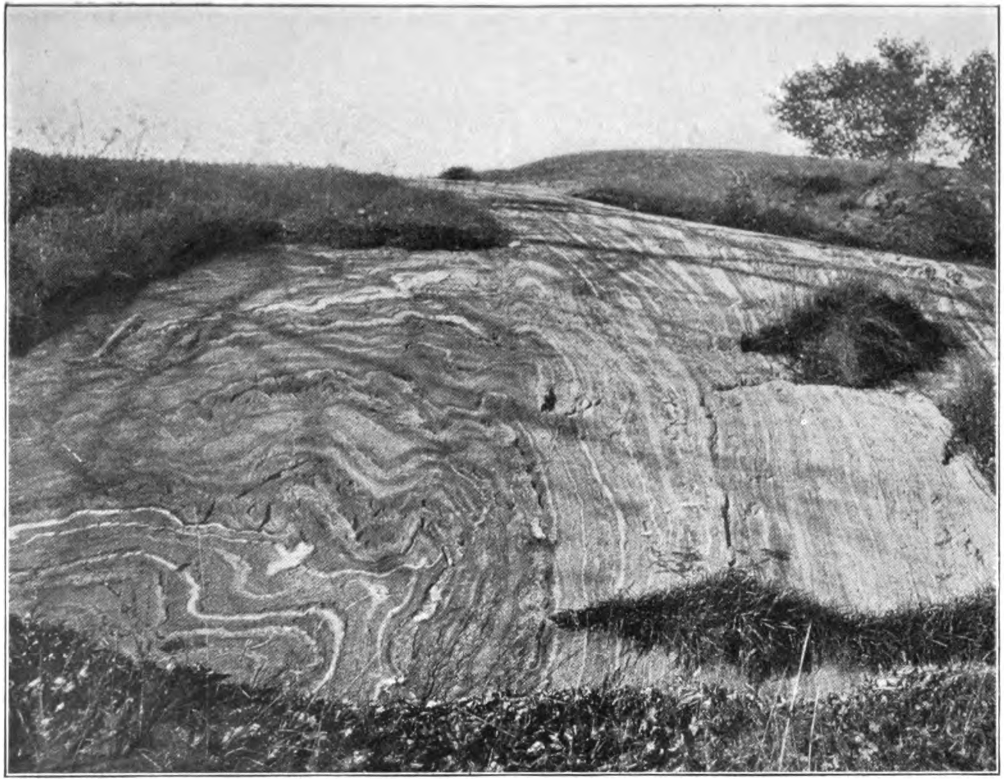
The best known of the Connecticut banded gneisses owe their structures largely to the fact that they have been injected and cemented after the development of schistosity; and, in fact, few gneisses within the state are free from material introduced along the planes of foliation. Plate XII shows a typical banded gneiss which has been injected during or after the time when the metamorphic structures were developed.

GRANITE AREAS.

Rocks of the parts of Connecticut covered by ancient crystallines have been so thoroughly metamorphosed that there is very little unaltered rock remaining. Granites which occur here are ordinarily gneissoid, like that in the Maromas quarry, and may be completely altered, or may show some of the original structures as at East Glastonbury and Derby. There are, however, some areas of granite which have been slightly or not at all affected by metamorphic processes, and which retain their original composition and texture. Such areas are small, rarely more than half a mile in diameter, and are distributed unevenly over the state, with, perhaps, a greater development toward the southeast.

The nature of these granite masses is not clear, but it is probable that they represent molten masses which were formed deep below the surface, and which are now exposed only because the overlying rocks have been eroded to a great depth. Many of these granite knobs are exposed to view along the coast, and here are located quarries which are of commercial importance. If the hypothesis above

PLATE XII.



BANDED STRUCTURE IN GNEISS, OTTAWA RIVER, NEAR MONTEBELLO.
From *Sixteenth Annual Report of U. S. Geological Survey.*

stated is correct, and if we imagine erosion to proceed much further, and perhaps an additional thousand feet of rock to be removed from the state, we should expect these granite knobs to appear in greater profusion, and the crystalline area, instead of being composed of gneisses and schists with a few small patches of granite, to be made up of granite with small bands of schists and gneisses between them. It is not supposed that these granite masses forced themselves into the rocks, lifting the strata above them, but that, as they invaded the overlying rocks, they quietly melted and assimilated them. Moreover, it is probable that the granites as they now exist are in large part made up of other rocks which have been molten and recrystallized. It is also probable that many of the granite areas now exposed are parts of chimneys or stocks of igneous rock, which reached entirely through the covering strata and poured out their molten mass as lava floods. All traces of such volcanic activity would have disappeared with the removal of the thousands of feet of rock which once covered the present surface. The age of these granite masses is unknown, but they are much younger than the surrounding gneisses and schists. Their age, relative to the metamorphics, is shown by the following facts:— they have not been subjected to the pressure which produces schistosity; they cut into and through the metamorphic rocks; and, occasionally, a fragment of schist or gneiss is included within the granite. For details regarding the structure and character of these granite areas the reader is referred to the discussion of the Stony Creek and other granite-gneisses of the shore line, and the Westerly granite (pages 147, 154).

PEGMATITES.

In addition to the granite masses mentioned above, there are found abundantly distributed over the state veins or dikes of coarse-grained rock composed largely of feldspar, quartz, and mica. These rocks resemble very coarse granite, and the individual crystals are commonly several inches,

and occasionally several feet, in diameter. One of the most interesting veins ever described occurs at Branchville, where single crystals were taken out which weighed from one hundred to two hundred pounds.

Such rock is called pegmatite. It has been termed "giant granite", but is not a true granite, and its origin is somewhat different from the ordinary igneous rock. It has been noticed that pegmatite occurs usually in veins from a few inches to one hundred feet or more in width and one hundred or more feet in length, though they may extend for thousands of feet. It is found that the composition of pegmatite generally varies in accordance with its distance from granite masses. Near the granite areas it closely resembles the true coarse-grained granite; farther away it is composed largely of quartz and feldspar, and at a still greater distance from the granite bosses pegmatite veins are apt to consist almost wholly of quartz. In this last case it is clear that the rock was formed like a quartz vein from aqueous solution; and, in order to account for the great variety shown in the same pegmatite vein, it is necessary to assume that pegmatite results either from aqueous solution, or from true igneous rock injection, or from the combination of the two. Water contained in rocks at high temperatures may carry large amounts of mineral matter in solution, and form what is practically a rock emulsion. The principle involved is stated by Van Hise, as follows:—" Under sufficient pressure and at a high temperature there are all gradations between heated waters containing material in solution and magma containing water in solution. In other words, under proper conditions, water and liquid rock are miscible in all proportions." Many pegmatite veins have crystallized from such aqueo-igneous masses, and are thus intermediate in character between veins and dikes, so that either of the two names may be applied to them.

These pegmatite veins, which are scattered so freely throughout the state, are the sources of quartz, feldspar, and mica of commercial value. In addition to the feldspar and quartz quarried from the pegmatites, as at South Glaston-

bury and New Milford, these veins have produced a variety of interesting and valuable minerals which have found their way to the museums of the world. In a vein of albitic pegmatite at Branchville, the following mineral species were found, several of them new to science:—albite, quartz, muscovite, microcline, damourite, spodumene (and its alteration products), apatite, microlite, columbite, garnet, tourmaline, staurolite, eosphorite, dickinsonite, triploidite, rhodochrosite, reddingite, amblygonite (hebronite), vivianite, lithiophilite, uraninite, fairfieldite, fillowite, chabazite, killinite, natrophilite, hureaulite.*

The Haddam Neck pegmatite is famous for its green and pink tourmalines, but produces also albite, microcline, green and pink apatite, red fluorite, beryl, quartz, cookeite, lilac lepidolite, greenish white muscovite, and a peculiar pink fibrous variety of the same mineral. Green fluor, microlite, columbite, also occur.†

Other pegmatite veins in the territory included in the towns of Middletown, Haddam, Chatham, Portland, and Glastonbury, have yielded sphalerite, gahnite, magnetite, chrysoberyl, bismutite, orthoclase (crystals), albite, oligoclase, beryl, iolite, garnet, epidote, tourmaline, muscovite (crystals), lepidolite, biotite, columbite, samarskite, monazite, triplite, torbernite, autunite, uraninite.

BASIC IGNEOUS ROCKS.

In the discussion of gneisses it was assumed that the typical Connecticut gneiss was a banded rock with a composition identical with granite. Some of the gneisses, however, are hornblendic, and have a composition which closely resembles that of diorite or gabbro. In addition to these hornblende gneisses there are areas of dark colored rock which have escaped the severer metamorphism and may be considered as distinct masses of basic rocks. As in the case of the granites, these are to be considered as bosses which

Am. Journal of Science, series 3, vol. XVI, pp. 33-46, 114-123, 1878; vol. XVII, pp. 359-368, 1879; vol. XVIII, pp. 45-50, 1879; vol. XX, pp. 257-284, 1880; vol. XXXIX, pp. 201-216, 1890.

†*Mag. and Journ. Min. Soc.*, vol. XIII, pp. 97-121, May, 1902 (4 figs., 1 plate).

have invaded the surface rock from below and are now exposed by erosion. It is, of course, possible that these areas are the deep-seated representatives of ancient volcanoes, and that they were once connected with the surface and gave rise to lava flows of which no trace remains. Typical ancient basic rocks within the state are the gabbro-diorite in Preston, and the norite in Litchfield. (See pages 111, 152.)

Diabase Dikes.— The crystalline rocks of Connecticut are of very great age, and a long time elapsed between their formation and that of the diabase and basalt of the Connecticut Valley. There are, however, within the crystallines, a number of dikes of diabase which are believed to date from the time of the formation of the Connecticut sandstones, and which are thus very much more recent than the schists and gneisses which surround them. These dikes are shown on the geological map published by the State Survey. It is evident, from their structure and their relation to the surrounding rocks, that they have not been subjected to the movements in the earth's crust which have produced the schistosity so prevalent over the state. They are, however, intersected with numerous joints, and have been broken by the faults which have given character to the topography of central Connecticut. The rock composing these dikes is dark bluish in color, is massive, is finely crystalline in texture, and is in no way to be distinguished, superficially, from the material composing East and West Rocks at New Haven, and the Barn-door Hills in Granby.

TOPOGRAPHIC EXPRESSION OF THE CRYSTALLINE ROCKS.

A large part of the state is less than five hundred feet above the sea level. The elevation increases from the shore line toward the northwest, the highest point in the state being Bear Mountain, in Salisbury, which is 2,355 feet above the sea. A number of points in the western crystallines, especially about Norfolk and Litchfield, are between 1,000 and 1,500 feet in height, while the high points in the eastern crystallines rarely exceed 1,000 feet. The higher ridges

throughout the state are composed of schist, and not, as might be readily expected, of the harder gneisses. The ordinary schist is apparently very easily decomposed, and, when fissile, gives ready access to water which aids in its destruction. The gneisses, however, contain much greater quantities of feldspar, which is the most readily decomposed of all of the common minerals found in crystalline rocks. The result is that ridges like Box Mountain, in Bolton, and Satan's Kingdom, in New Hartford, although made of finely foliated schist, stand high above the gneisses which surround them. The chief topographic features of the area occupied by crystalline rocks are the elongated hills extending in a direction from a little east of north to a little west of south. This is the general direction of the foliation of all southern New England, and this structure has been a controlling factor in producing the form and direction of the hills. The main faults of the region are also northeast-southwest, and are an additional factor in determining the topographic relief. This direction is, of course, only general; there are many exceptions, and erosion has produced hills of a great variety of form.

Wherever quartz is abundant in the rock, erosion proceeds more slowly; and accordingly pegmatite dikes and quartz veins may stand out prominently. Certain hills in Plymouth, Barkhamsted, and New Hartford, and the White Rocks of Middletown owe their preservation to pegmatite veins. Lantern Hill, in North Stonington, is a quartz mass of unusual size. On a smaller scale, pegmatite and quartz veins occur as combs along the higher ridges. The prominent ridge of Great Hill, or Cobalt Mountain, on the boundary between Portland and Chatham, is capped by an extremely resistant quartzite.

The hills of the crystallines do not show rugged or precipitous outlines. This is due, not to the character of the rock, but to the fact that the entire region has been overridden by the continental glacier of the Glacial period, and the minor irregularities have been effaced. The direction of glacial motion was approximately from north to south, some-

what in line with the main rock structure, and has thus served to intensify the north-south course of the principal topographic features.

The general structure of Connecticut as a series of north-south ridges will be readily appreciated when the location of the railroad lines is observed. The Naugatuck Division and the Vermont Central, which run through the ancient crystallines throughout their extent in Connecticut, were inexpensive roads to build. There were no heavy grades, and no great fills or costly bridges to be made. The Hartford Division and the Northampton Division take nearly straight lines, and were practically built on a plane throughout their extent. If, on the other hand, we consider the Air Line Division, the Highland and Midland Divisions, and the Central New England, we see the great difficulties which are encountered in building a road from east to west. The Air Line from Middletown to East Thompson has heavy grades, and the entire road-bed is a series of expensive fills, deep cuts, and high bridges. The Highland Division from Willimantic to Danbury winds back and forth across the state, and goes many miles out of its way in order to escape the ridges in its natural path. These same features are exhibited by the Central New England, which crosses the Western Highland at an altitude of over 1,300 feet. Throughout its extent it is an almost continuous series of curves. If a road were to be built directly across the state, east and west, from Sharon to Putnam, or from Danbury to Norwich, the cost would be greater than commercial operations would justify, and the building would be little less difficult than railroad work in mountains. The financial history of these roads has been directly related to their geographical location, for less favorable location means increased cost in both construction and operation.

GEOLOGICAL HISTORY OF THE CONNECTICUT CRYSTALLINES.

The length of time since life first appeared on the earth is to be measured by tens of millions of years. The time

recorded in the series of fossiliferous strata has been divided for convenience into several eras, called Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Jurassic, Triassic, Cretaceous, Tertiary, Quaternary — each system being marked by characteristic fossils. Before these come the Archæan, showing no evidences of life, and the Algonkian, with only doubtful traces of life. An immensely long time it must have been before the earth was adapted for living forms. Fossils are the most readily applicable means of determining the age of rocks, and the only fossils found within the state are those of the Triassic sandstones — chiefly fishes, reptiles, and plants. There is, therefore, no formation within Connecticut older than the Triassic, whose age has been definitely determined by the examination of the rocks themselves. Their position in the time scale can be determined only by comparison with other regions where similar rocks are present in known relations. By combining such comparison with the study of the structure of the rocks themselves, it is found that the crystallines within the state have had a long and complicated geological history, beginning before the earliest fossiliferous strata were deposited.

Rocks older than the Cambrian exist in Connecticut, but we are ignorant of their origin and exact age. They may have been sediments containing fossils, or they may have been igneous masses. Whether they represent the Archæan or the Algonkian system, or both, is unknown. Their position and structure and texture are so altered by metamorphism that all evidences which might be used in determining their age have been destroyed. There is, however, little warrant for assuming in general that the gneisses and granites of Connecticut represent parts of the "original earth's crust." The Becket gneiss and certain other formations in Connecticut are believed to be pre-Cambrian, although without conclusive evidence.

A study of the Cambrian rocks of North America shows the distribution of land and water to have been very different from the present. There are some facts that suggest that Connecticut was under water, and that a land mass ex-

isted to the eastward beyond the present shore line. It has been fairly well demonstrated that a sea or bay of salt water stretched across western New England and up to the St. Lawrence. The extent of this Cambrian sea is unknown; but part of the marble of the Housatonic valley is believed to have been made from calcareous mud deposited at that time; and the quartzite at Poughquag, just west of the Connecticut border, is believed to be the metamorphic representative of a Cambrian sandstone.

During the Ordovician period the conditions for the deposition of sediments continued, and sandstones and shales and calcareous deposits were formed. The calcareous material is now represented by the upper part of the limestone of western Connecticut and Massachusetts, and the shales and sandstones are believed to have been the originals from which certain schists were developed by metamorphism. The accumulation of these sediments implies the wearing down of the adjacent lands, perhaps to a plain.

In western Connecticut no definite record is left of the long interval of time between the Ordovician and the Triassic. The absence of known Devonian and Carboniferous strata, and the facts which are known in regard to the geological history of eastern North America in general, suggest the belief that the state during these ages was part of a land mass bounded on the west by a salt-water sea and on the east by the ocean. Moreover, it is believed that Devonian time saw western New England molded into mountain ranges, and witnessed their disappearance into land of less relief. The inference that an area of dry land existed in western New England during Devonian time, rests upon the fact that the fossils found in Maine are unlike those of corresponding age found in New York, thus indicating the presence of an isthmus separating two water bodies in the northeastern United States. Then again, the sediments of Devonian age both east and west of Central New England show a retreating shore line, as if the land were rising along a northeast-southwest axis. The great thickness of Devonian sediments in the region to the west — 5,000 to 10,000

feet — indicates that the land area of New England constituted a mountain range comparable in height to the southern Appalachians and perhaps even rivaling the Alps.

Between the Ordovician and the Triassic occurred the universal metamorphism of the sedimentary deposits, with the intrusions of igneous rock and the formation of the numerous veins of quartz which form such characteristic features of the metamorphic crystallines. The portions of the intrusive masses now exposed to view cooled and crystallized beneath the earth's surface; but it is reasonable to assume that part of the molten rock reached the surface, and gave rise to volcanic phenomena, all traces of which have now disappeared. The date of these intrusions and details of their character are unknown. All that can safely be said is that they represent different periods of igneous activity and occurred between the Ordovician and the Triassic. Metamorphism of the pre-Triassic rocks occurred at some date or at several different dates later than the original deposition of the rocks. The exact time when these great changes took place cannot be stated, but the metamorphism in large part seems to have been associated with the mountain-making movements which were so marked near the close of the Carboniferous. A wide extent of territory in the eastern part of the United States was affected at this time, extending from the St. Lawrence to Alabama. Sediments which had been accumulating for ages were forced into smaller compass. Along the present Appalachians the rocks were folded into arches; and the more severe compression in New England resulted in profound alteration of the rocks and the production of slates, schists, and gneisses. The result is that no unchanged sediments of pre-Triassic age exist in Connecticut, but their metamorphosed equivalents are present everywhere. The igneous intrusions have likewise been forced in many places to develop schistosity and to take on gneissoid structure.

In brief, then, the history of Connecticut previous to the deposition of the Triassic materials seems to be as follows: The region was submerged beneath an extensive sea until

late Silurian times. During Devonian time mountain masses rose and disappeared. Throughout the Carboniferous era the state probably remained a land area, and near the close of this period the great metamorphic changes were produced.*

Indications of Paleozoic History in the Structure of the Crystallines.—As we have already seen, the crystalline rocks are chiefly schists and gneisses, and accordingly have structures indicating that they have been profoundly changed from their original sedimentary or igneous character. The original component minerals have been rearranged, stretched, and drawn out in lines; new minerals have been produced; parts have been fused and recrystallized. Instead of horizontal layers or uniform igneous masses, we find twisted and broken rock with layers, bands, and ribbon structures in every conceivable position. Moreover, this tangle of structure is further complicated by the presence of dikes, seams, and veins which have made their way into the rock at different stages of its history. In looking at this confused mass of rock which forms the Connecticut crystallines, it seems apparent that it has taken part in manifold changes which went on in the earth's crust for ages. This very complexity of structure and composition is an important aid in determining the relative age of the rocks, for it is evident that in general the oldest rocks must have been affected by the greatest number of disturbances, and accordingly the rocks of one age may exhibit structures not found in those of succeeding ages. In the absence of other criteria the geologist is forced to fall back upon this. These rocks are like a sheet of parchment on which writing after writing has been placed at different times by different hands, without at any time completely erasing the previous inscriptions. Little wonder that we have difficulty in deciphering the original writing!

* The outline of geological history given above is based on data published by the New York State Survey and the United States Geological Survey, and relates primarily to western Connecticut. Very little is known regarding the order of succession and age of the schists and gneisses of eastern Connecticut. Such conclusions as seem probable regarding their history are stated in connection with the descriptions of the formations in Part II of this chapter.

its stratigraphic position. The Poughquag quartzite and the Stockbridge dolomite seem to be satisfactorily placed in the time scale by facts collected beyond the borders of Connecticut; and, if the Pomfret phyllite is identical with the fossiliferous phyllite at Worcester, a time horizon is established for the eastern part of the state. But, to say the least, the absence of fossils in these ancient rocks makes correlation difficult, and the results so far attained are unsatisfactory.

From what has been said it is evident that, from the standpoint of exact science, a satisfactory geological report and map of the Connecticut crystallines can not be made at the present time. The data are incomplete, and the interpretations are open to question. Under such circumstances it might be considered wise to delay the publication of a handbook until the entire region had been studied in detail by a group of trained specialists. It has seemed best, however, to present such facts as are available, and to put into the hands of those interested in Connecticut geology some work which will enable them to understand the main facts regarding the rock formations about them. This is deemed especially desirable since the complete study of the geological details may not be carried out for a number of years.

The data upon which the following descriptions and also the geological map are based, come from several sources, but chiefly from unpublished manuscripts written by officers of the United States Geological Survey and the Connecticut Geological and Natural History Survey. The region west of the 73d meridian has been surveyed by Professor W. H. Hobbs and assistants. The Litchfield Folio (containing a geologic map and descriptions of the area covered by the Cornwall, Winsted, Danbury, and Waterbury topographic sheets) is nearly ready for publication by the United States Geological survey. Credit should also be given to Professor J. D. Dana, who spent much time in the western part of the state, and to whom we owe our first accurate knowledge regarding the structure and relationship of the limestone areas of Connecticut and eastern New York.

schists, as might be expected from the intense metamorphism to which they have been subjected. With the exception of pegmatite veins and small dikes of granite, and portions of the Preston gabbro, the Brookfield diorite, and some of the granite-gneiss areas, there are no rocks within the crystalline areas whose structure has not been markedly affected. It is customary to use the term "granite" for rocks consisting essentially of quartz and feldspar with mica or other dark mineral, as, for example, the "Westerly granite", the "Stony Creek granite", or the "Glastonbury granite". Strictly speaking, however, there are no areas of granite within the state large enough to be represented on the published geologic map. Granite, when the word is used strictly, is a rock massive in structure, with crystals of quartz, feldspar, and usually mica, all about of one size; its component crystals are not drawn out into lines, and foliation planes are not present in it. The development of foliation or schistosity by metamorphism produces a gneiss. A granite in which metamorphic action has developed a gneissoid structure, is a gneissoid granite, or, better, a granite-gneiss. The term "gneiss" implies nothing as to composition, but refers entirely to the surface appearance and structure of the rock. Thus we have Brookfield diorite-gneiss, Bristol granite-gneiss, etc. In this publication the word "gneiss" used alone is restricted to those formations possessing gneissoid structure which are believed to be sedimentary in origin (for example, the Putnam gneiss), or those whose origin is in doubt (for example, the Becket gneiss). In naming the rock types, field appearance and examination with a hand lens have, in the main, been relied upon; and it is altogether probable that laboratory study will result in a changed classification. Doubtless, also, rocks of unlike character will be found to have been placed in a single formation.

The age of the Connecticut crystalline rocks is uncertain, and whatever is said in this report as to their probable age is subject to radical revision. No formation within the crystalline area of the state has yielded direct evidence as to

PLATE XIII.

UNCONFORMABLE CONTACT OF HARTLAND SCHIST AND TRIASSIC SANDSTONE, ROARING BROOK, SOUTHINGTON.

Photograph taken under direction of W. M. Davis for U. S. Geological Survey.

Such composition and structure as is described above can be produced only at very great depths in the earth (probably below 20,000 feet), where rocks are so deeply buried that, whatever the lateral stress, they will not adjust themselves by breaking, but by plastic deformation. It is therefore certain that, whatever the age of the crystallines, mountain ranges perhaps rivaling the Alps in height and ruggedness once occupied central Connecticut; and, when we examine the rocks of Satan's Kingdom, or the Quinnebaug Valley, or the Connecticut gorge below Middletown, or indeed any part of the area of crystalline rocks, we are studying the roots of lofty land masses composed of strata deposited during part or all of the Paleozoic era.

In a few localities these crystalline rocks are seen in contact with the Triassic sandstones. One such locality is the ravine of Roaring Brook, in Southington, two and one-half miles northwest of Plantsville.

The crystalline rocks exposed in the ravine of Roaring Brook belong to the Hartland (Hoosac) schist — a formation which occupies a large area in New England, and of which a special description is given on page 96. The schists are inclined at high angles, and their tops are irregularly eroded away. Lying directly upon the upturned edges of the schists are the brown sandstones and conglomerates of the Triassic, slightly tilted to the east, but otherwise unchanged since their original deposition and consolidation. The schists are the stump of a mountain range; the sandstones were deposited by water after the mountains had been reduced to a stump. Such a relation as is here exhibited between the schist and the sandstone constitutes an "unconformity", and means a lapse of time between two rock series. In the Roaring Brook section the lapse of time is from Silurian to Triassic — untold millions of years,— and the amount removed from the schists is unknown thousands of feet. Considered from this standpoint, the section exposed in the bank of Roaring Brook, as shown in Plate XIII, is one of the most impressive views within reach of the student of nature.

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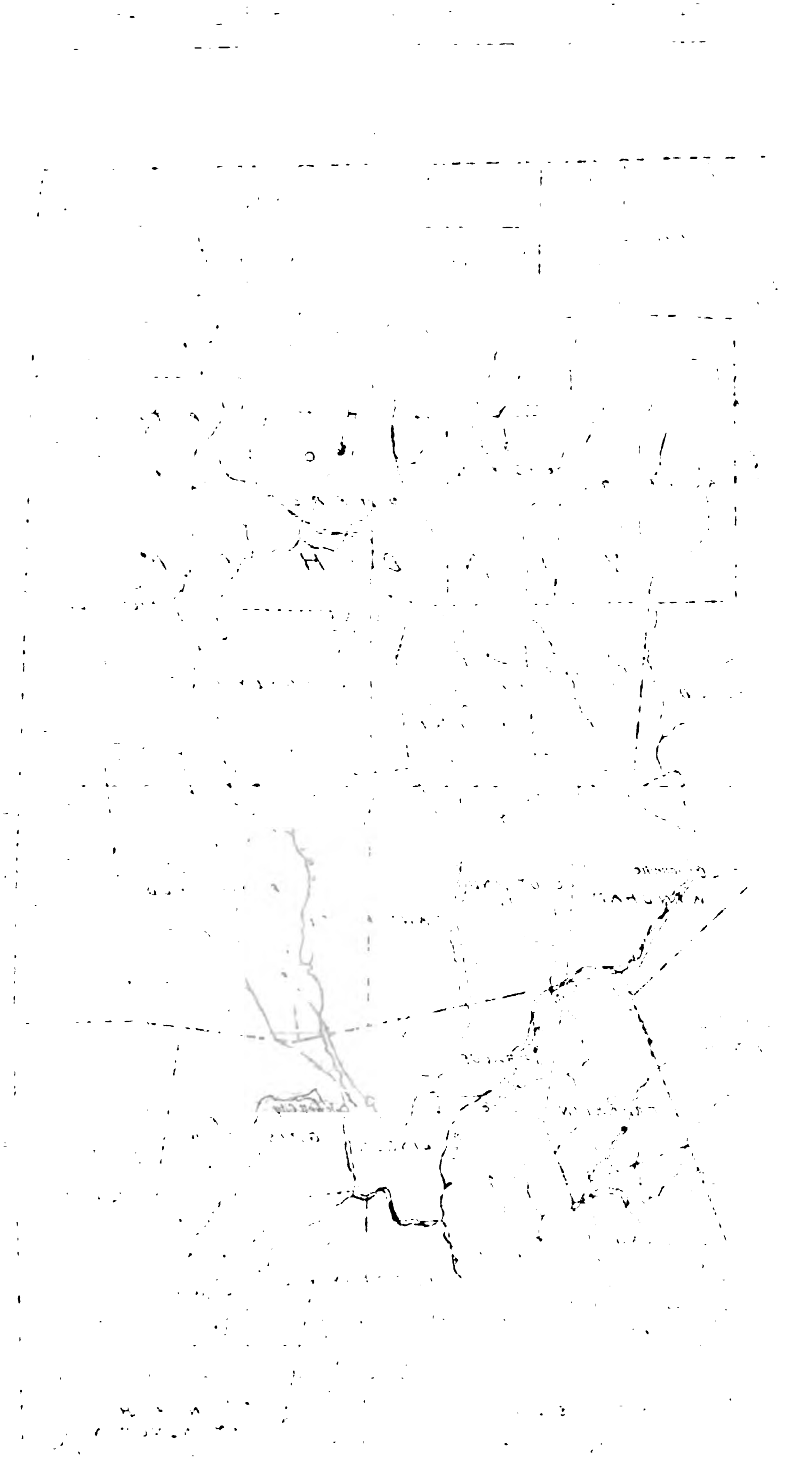

The crystalline rocks bordering the Triassic north of a line through Higganum and Prospect have been studied by Professors Herbert E. Gregory and Lewis G. Westgate. The results of this work will appear in a report on the Farmington Quadrangle (consisting of the Granby, Meriden, Hartford, and Middletown sheets of the topographic atlas) to be issued by the United States Geological Survey. The eastern part of the state has been mapped only in a preliminary way under the auspices of the United States and the State Survey, by Professor Gregory and Dr. H. H. Robinson, assisted by Dr. C. H. Warren, Dr. W. E. Ford, and Dr. G. F. Loughlin.

Previous to the recent work carried on by the Federal and State Surveys no general work on the crystallines had been undertaken since Percival's "Geology of Connecticut" appeared in 1842. In that report important rock formations are distinguished and described, and marked off on a geological map. Percival's field observations were remarkably correct; but the nomenclature used by him, and his method of representing formations on the map, are such that it is practically impossible for the average reader to use his classic work intelligently.

With the exception of the smaller dikes, veins, etc., the formations described in this chapter are shown on the accompanying map (Pl. XIV). In making the geographic base for this map the Southern New England Telephone Company's map, on a scale of about three miles to the inch, was used. It has been simplified, however, by omitting roads and most of the names. Only a few of the rivers have been named, but others may be readily identified by reference to the topographic map of the state. Small circles give the location of villages or cities. Those villages or cities which have the same name as the town within which they are situated are not named. Stations on railroads are indicated by black dots, and have been taken from the railroad time tables. Boundaries of geologic formations are shown as red lines, and each formation is numbered in red, according to the legend at the left side of the map.

GEOLOGICAL FORMATIONS OF THE WESTERN HIGHLANDS.

With the exception of a small area of Triassic rocks in Woodbury and Southbury (see page 160), the entire western part of Connecticut, bounded by a line extending from New Haven to North Granby, is composed of ancient crystalline rocks. The distinct formations here represented are—the Becket gneiss, which is regarded as a pre-Cambrian complex equivalent to the Fordham gneiss in the vicinity of New York City; the Poughquag quartzite, of Cambrian age; the Stockbridge limestone, of Cambro-Ordovician age; the Berkshire (Hudson) schist, of Upper Ordovician age; and the Hartland (Hoosac) schist, probably of Silurian age. The Waterbury gneiss is Hartland schist modified by igneous injections. In addition to these there are igneous masses; namely, the Danbury granodiorite-gneiss, Brookfield diorite, Thomaston granite-gneiss, Collinsville granite-gneiss, Bristol granite-gneiss, Prospect porphyritic gneiss, Litchfield norite, areas of peridotite, and numerous amphibolite dikes and pegmatite veins. In the southeastern part of the district are found the Orange phyllite and the Milford chlorite schist.

Poughquag Quartzite§ [1] is distributed over the western part of the state with little order, and is restricted to isolated areas surrounded by other crystalline rocks. It occurs on Rattlesnake Hill in North Canaan, on the north and east sides of Barrack Hill, on the north flank of Cream Hill in Canaan, and on Sharon Mountain. It also occurs on the highlands west of Swift Bridge. Strips are found in Kent west of the Housatonic River, and likewise at South Kent. It occupies the south shore of Bantam Lake, extending from Little Mt. Tom eastward to the branch of the Naugatuck River. Small areas also appear west of Milford and west of Orange Center. Rock belonging to this formation

§ The descriptions of the formations west of the 73d meridian are based largely upon the work done by the United States Geological Survey under the direction of Professor W. H. Hobbs. Parts of this chapter are taken almost in their present form from the unpublished manuscript of the Litchfield Folio. This statement applies particularly to the descriptions of the Poughquag quartzite, Stockbridge dolomite, Berkshire schist, Brookfield diorite, Thomaston granite-gneiss, and Litchfield norite.

is found in northwestern Massachusetts, southern Vermont, and eastern New York, and is described in geological works as Cheshire quartzite. Similar rocks occur in a number of localities east of the Connecticut River, as will be described later; but whether or not they are of the same age is unknown.

The rock appears under two types. The first is a massive granular quartzite, composed largely of quartz and feldspar, the latter being microcline and orthoclase with a small amount of plagioclase. The feldspar may equal or even exceed the quartz in amount. Ordinarily mica is also present and is generally biotite. Where this rock has been exposed to the atmosphere for any length of time, it has weathered to a dull brown color, due to hydrated iron oxide. The schistose type, as found in Morris, is much more micaceous, and has a well developed schist structure. As seen in the field, it is quite unlike the granular rock of Sharon Mountain, but is believed to be a modification of the same formation.

Between Falls Village and Cornwall Hollow opportunity is offered for measuring the thickness of the Poughquag quartzite. Here the rock dips conformably beneath the Stockbridge limestone, and is believed to envelop an elongated dome of Becket gneiss. The measured thickness at this locality is between 700 and 800 feet. That the Poughquag quartzite is an altered sandstone is shown by the fact that often, even where it is most metamorphosed, fragments of the original sedimentary material occur in it. In certain places farther north the quartzite is so little changed that fossils have been found in it, thus determining its age as Upper Cambrian.

Stockbridge Limestone [2].— Metamorphosed dolomitic limestone is a prominent formation in the eastern United States. It is abundantly exposed in the upper Housatonic valley, and has received the general name of Stockbridge limestone, because of its occurrence at Stockbridge, Massachusetts. In Connecticut all the exposures of any importance are in the western and northwestern part of the state. A wide belt extends from Canaan Valley southwestward to

Sharon, and underlies a large portion of the towns of North Canaan, Canaan, and Salisbury. A narrow belt extends from Cornwall Bridge to Gaylordsville, forming the valley of the Housatonic River. A smaller belt, rarely attaining a mile in width, extends from New Preston through Marbledale, Northdale, New Milford, Brookfield, and Danbury, to West Redding. In the vicinity of Danbury this belt widens and sends an arm westward to the New York line. An area somewhat detached from the main belt occurs at Ridgefield, and a number of small limestone areas are found in other parts of the state, as at Winsted, Robertsville, East Hartland, Long Hill, and at a few places east of the Connecticut River. These small detached areas are identical in composition with the main masses of the Stockbridge limestone, and it may be that most of them are parts of one general formation, and owe their isolated position to accidental circumstances. There is, however, no direct proof of this. Beyond the borders of the state the Stockbridge limestone is found in more or less parallel belts which extend from Vermont to Georgia and include some of the most important building stones of the United States.

The Stockbridge limestone is one of the few geological formations in Connecticut possessing characteristics which enable the geologist to interpret without doubt its origin and geological history. The region occupied by this rock — the northwestern part of the state—has been made classic ground by Professor J. D. Dana. His papers on this region in the *American Journal of Science,* series 3, vols. IV, V, VI, and XXIX, show the care with which the outcrops were studied and the skill used in solving the difficult structural problems there presented. The work of Professor Hobbs in this region has added important new data, and the results of his study are to appear in the forthcoming Litchfield Folio, to be published by the United States Geological Survey. Professor Hobbs's acquaintance with the same formation in Massachusetts and in New York has enabled him to interpret the Connecticut structures and to add much new information.

The Stockbridge limestone is important economically, for in it occur the iron mines of Salisbury, Connecticut, and of Columbia and Dutchess counties, New York. The rock is burned for lime, and is an important building stone. The marble of the State Capitol at Hartford was quarried at Canaan, and the stone for the National Capitol at Washington was taken from the same belt farther north.

Because of its slight resistance to erosion the limestone usually constitutes valley areas. It is the natural channel of the Housatonic River; and, wherever the river has deserted the limestone bed, it has done so because of special structures in the rocks or because of the modifications produced by the ice sheet.

The Stockbridge limestone is a light gray marble of medium grain, having a thoroughly crystalline texture, and composed chiefly of calcite and dolomite. The relative proportions of calcite, dolomite, and impurities are shown by the following partial analyses made from specimens at Lime Rock and Sharon:—

	Lime Rock (1)	*Lime Rock* (2)	*Sharon* (1)	*Sharon* (2)
CaO	52.09	27.78	36.03	28.96
MgO	.47	16.93	17.76	18.54
SiO_2	4.11	4.21	4.00	9.98

The analysis of the rock at the Ashley Falls Marble Co., made by Messrs. Ricketts and Banks, gives the following results:—

CaO	30.03
MgO	21.57
CO_2	47.42
SiO_2	.28
Al_2O_3	.07
Fe_2O_3	.43
S	.03
Na_2O	.16
K_2O	.04
	100.03

This analysis shows that the Stockbridge formation at this locality is a typical dolomite, composed almost entirely of carbonates of lime and magnesia in proportions of 53.63 per cent. of the former and 45.07 per cent. of the latter.

A characteristic feature of the limestone is the presence of imbedded metamorphic minerals, some of them attaining large size, and all of them formed since the rock was deposited. The most distinctive of the minerals is a white pyroxene (diopside), which is known to quarry men as "Jason's teeth." It occurs usually in flat crystals, with characteristic octagonal cross-section. It frequently exhibits a silky surface owing to the development of tremolite, a variety of amphibole similar in composition to diopside. In the New Preston valley the tremolite is developed in plumose or fan-shaped groups of needles, which attain the dimensions of an inch or more. A yellowish brown mica — phlogopite —is also characteristic of dolomite, and occurs abundantly as minute scales. In places sericite is developed in such quantities as to alter the rock to a calcareous mica schist. In the Mt. Washington region the dolomite is occasionally graphitic. Chondrodite, pyrite, chalcopyrite, black calcite, clinochlore, and talc, also occur.

A modification of the Stockbridge limestone occurs in a number of localities, and has been named by W. H. Hobbs *canaanite*. It forms ridges of a few rods in width, but usually of considerable length, and is a white rock which weathers to a dark gray ragged or cellular surface. It is composed chiefly of diopside, and is believed to have been formed from the Stockbridge limestone by solution along the lines of fracture. A ridge of silicified dolomite extends between Falls Village and Canaan for a distance of about four miles. This ridge rises from the otherwise nearly level valley of the Housatonic, and its topographic form has apparently been determined by the fact that the Stockbridge limestone has been modified and hardened along this line. When the rock composing the ridge is examined, it is seen to have a framework consisting of interlacing veins of quartz. Within the meshes of this network is found the Stockbridge

limestone, showing an unusually coarse texture, in which are developed large crystals of tremolite and diopside. The tremolite occurs in distinct stars or wheels, the individual crystals being sometimes several inches in length. This silicified type of the Stockbridge limestone is believed to have been the result of crushing along the line of faulting. The rock was shattered, and later the fragments were cemented by water bearing silica in solution.

The lower part of the Stockbridge limestone was originally a calcareous mud deposited in shallow, widespread seas during Cambrian time. Part of it is of Lower Ordovician age, and there seems to have been no physical break between the Cambrian and Ordovician in this locality. The formation is so complicated by a series of close overturned folds, severe deformation, fracture, and faulting, that it is impossible to determine its thickness with accuracy; it is probable that its thickness varies within wide limits, and that in places it thins out until it entirely disappears. Along the border of the ancient land masses the formation is believed to have a thickness of five hundred feet or more.

Berkshire (Hudson) Schist [3] is a widespread formation in western Connecticut, which extends into Massachusetts and southward into New York. It may be roughly divided into two areas. The first occupies the extreme northwest corner of the state, including Bear Mountain, Indian Mountain, and a number of small hills which rise above the limestone of the Canaan-Salisbury district. The second area forms a long irregular line extending southwestward from Norfolk, and has its greatest and most characteristic development in Goshen, Cornwall, Warren, and Kent. An area also extends from Winsted northward to the state line. The New York City Folio contains a description of this rock at the southernmost extension of the belt. In the Salisbury region the formation is generally a gray or greenish gray muscovite-biotite schist, with rusty foliation planes, and usually closely folded. In places the rock has a greenish tinge, and passes into a chlorite schist or even a graphite schist toward the base of Mt. Washington. Porphyritic

minerals are imbedded in the schist, and their method of occurrence shows that they have been formed since the deposition and consolidation of the rock. These porphyritic crystals are usually feldspar and garnet, but staurolite, biotite, and tourmaline also occur. Fibrolite is sparingly present in the more metamorphosed phases of the rock, and red garnet and staurolite sometimes become so abundant as to form nearly all of the mass. The Berkshire schist in the eastern belt is usually less schistose, and its planes of foliation are less sharply folded. It is also much more modified by injections of granite and pegmatite; hence it often takes on a gneissoid appearance.

In the vicinity of the granite areas the schist assumes a knotty character, and the pegmatite veins are so abundant as to constitute a marked local variation. These pegmatite veins, from a few inches to a rod or more in width, are often visible at considerable distances, owing to the white appearance produced by the large amount of feldspar. The knots which form a characteristic feature of the eastern belt, vary from one-eighth to one-half inch in diameter. Usually they contain garnets, and often the garnet is a nucleus about which knots have developed. Except for the garnets, which are red, the knots are generally white or gray in color, and are sometimes connected with each other by threads or filaments of the same material. The knots are usually more resistant than the mass of rock in which they occur, and for that reason give the surface a peculiarly rough or cellular appearance. In addition to the garnets, these knots contain white pyroxene and feldspar, with smaller quantities of tremolite, sphene, biotite, apatite, magnetite, quartz, fibrolite, and epidote. In the vicinity of Norfolk the knots are mainly muscovite, quartz, and fibrolite.

Because of the large amount of granite and pegmatite injection the Berkshire schist may be readily mistaken for Becket gneiss, which it closely resembles in places. The gneiss, however, is much less micaceous, much less crumpled, and usually contains a greater amount of feldspar. The relation of the Berkshire schist to the rocks above and

below is well made out in localities in New York, Connecticut, and Massachusetts. Certain sections along the Central New England Railway show that it is conformable with the Stockbridge limestone; that it is above the Stockbridge is shown in certain localities near Salisbury, the north end of Barack M'teth, Turnip Rock, and Watawanchu Mountain. In a number of localities in and near New York City it is also found to overlie this limestone. The transition between the two is gradual. They are separated by a zone of calcareous schist and micaceous dolomite, ten to fifty feet in thickness, grading into the limestone below and the typical schist above.

The age of the Berkshire is Upper Ordovician (Hudson). It is found that the Berkshire schists of New York City connect stratigraphically with the slate and shale along the Hudson River to the north; and it is believed that slate, shale, and schist are but phases of the same rock. Where unmetamorphosed, it is typically shale; where metamorphosed to a slight degree, it is a slate; and where the metamorphism has proceeded to a very advanced stage, the rock becomes the typical Berkshire schist, with all traces of its former structure lost.

Becket Gneiss [4].— Large areas in western Massachusetts and Connecticut are occupied by a banded gray rock of fairly uniform appearance and much injected by basic and acid intrusions. This rock has been named Becket gneiss, from the town of Becket, Massachusetts, where it is well exposed and quarried for building stone. It forms a large part of the northern boundary of the state in Hartland, Colebrook, and Norfolk, beginning west of the East Branch of the Farmington River, and constitutes the plateau of western Hartland and Barkhamsted, where it is traversed by the West Branch of the Farmington River. Its greatest development in this region is in the towns of Winchester, Goshen, Sharon, and Cornwall. Considerable areas are found in Warren, Washington, and New Milford; and a series of areas extends, with some interruptions, to Norwalk. Small detached areas occur elsewhere. Farther to the

southwest, the rock appears as the Fordham gneiss on the maps of the New York City Folio.

Where typically developed, as at New Hartford, the Becket gneiss is light gray in color, of firm texture, and has a uniform banded structure produced by the segregation of biotite along certain planes, so that layers composed chiefly of feldspar and quartz alternate with those rich in biotite. These bands are usually less than an inch in width, and show great variation in tones of gray, depending on the abundance and character of the mica present. In places the gneiss is highly quartzose and granular; elsewhere, as in parts of West Hartland, the gneissoid structure is so poorly developed that the rock might be called a granite, composed of feldspar, quartz, muscovite, biotite, and garnet. Where the gneissoid bands are very thin, the rock grades into a feldspathic schist, and in places is scarcely distinguishable from parts of the Hoosac formation. Microscopic examination shows the Becket gneiss to be composed of feldspar, quartz, and biotite, with smaller amounts of garnet, titanite, apatite, magnetite, and zircon. Muscovite is present in small amounts, and in some localities becomes an important constituent. Hornblende rarely occurs. The most abundant feldspar is microcline, but orthoclase is common, and there is also present a plagioclase which is usually albite.

Considered as a formation, the Becket does not appear as the uniform gray, banded rock described above, for it includes many schistose phases and also the ancient intrusions which have had the gneissoid structure developed in them by metamorphism. Thin granitoid layers, sometimes almost white from the absence of biotite, are interbedded with the gneiss, while layers of hornblendic gneiss and schist frequently occur. These parallel, interbedded layers, granitic, micaceous, and hornblendic, vary in width from a few inches to over one hundred feet, and, at irregular intervals, are intercalated with the more typical portions of the Becket, usually constituting elongated lenses rather than definite beds of great length. Included within this formation are many quartz veins, and also veins of pegmatite composed

of coarsely crystalline feldspar, quartz, biotite, and muscovite in variable proportions. Rarely magnetite, beryl, and tourmaline are found in them. These pegmatite bands occur parallel with the main direction of the schistosity of the gneiss, or cut across the beds at various angles. They are seldom over 25 feet in width, and do not usually extend continuously for more than a few hundred feet. In a few places the Becket gneiss includes a coarse granite-gneiss with a prominent red feldspar. Such areas are found upon Cream Hill in Cornwall and on the slope to the west of Cornwall Bridge. Smaller areas are found north of Torrington, near Daytonville, and in New Hartford.

It is not possible to state definitely the age, the thickness, or the original nature of the Becket gneiss. It is probably the oldest formation in the region, since it is cut by all the intrusions, and has been shown by Emerson to underlie unconformably the Hoosac (Hartland) schist. It is ascribed with some hesitancy to pre-Cambrian time. There are no criteria for determining the original thickness of the Becket gneiss. It contains no characteristic beds which may be used as standards of reference. Its original thickness has doubtless been increased and repeated many fold by folding and compression, and there is evidence that a large but unknown amount of faulting has further modified the initial thickness. The former nature of the beds is equally uncertain. It seems probable that they represent an area of granite which has been injected by various igneous masses at different times and subjected to intense metamorphism while yet deeply buried within the earth. On this hypothesis the more granitoid phases are most like the original rock, and the schistose varieties are most metamorphosed. The hornblendic and granitic beds were intruded before or during the chief metamorphic movement, and owe their position and alignment to the forces that produced the main foliation. Veins of quartz and pegmatite were intruded after most of the metamorphism had taken place, and certain intrusions indicate even a later stage of igneous activity.

Whether the rock now represented by the Becket gneiss was formerly igneous or sedimentary, its original attitude and texture have been destroyed by movements in the earth's crust. The number and sequence of these movements is unknown, but sufficient deformation has taken place to produce throughout the entire formation a distinct foliation which is seen in the field as well as in hand specimens. The microscope shows that the quartz and mica have identical orientation, thus producing parting planes; also that the crystals composing the rock are often crushed and broken into lines, and that other structures characteristic of metamorphic rocks are present. Most of the rocks intruded into the Becket have likewise had their identity destroyed by general metamorphism. The diorites and gabbros have become hornblende schist or impure soapstone and asbestus, and only rarely, as at New Hartford railroad station, does an amphibolite show clearly its dike-like habit. The forces which produced the compression in this area acted principally from the southeast, thus causing planes of schistosity which extend in a northeast direction, and which are usually so steeply inclined that only the edges of the layers are exposed to view.

Hartland (Hoosac) Schist [5].— The Hartland (Hoosac) schist in Connecticut is the southern continuation of large areas of rock on Hoosac Mountain and in adjacent regions of Massachusetts. Where it enters the state, it is a belt of schist six miles wide, forming a plateau between the Farmington River and the western border of the Triassic, in Hartland, Barkhamsted, Granby, and Canton. South of the Farmington River it includes Satan's Kingdom and other highlands in New Hartford and Burlington, extends in elevated ridges and hills to Plymouth, and forms the Wolcott plateau. This formation continues southwestward as a narrow ridge, through Prospect, Bethany, Beacon Falls, Naugatuck, Oxford, and Seymour. It forms Beacon Hill, Andrews Hill, Huntington Hill, and the highlands west of Seymour village. A second area extends almost uninterruptedly as a belt three to six miles wide from near East

Litchfield to beyond Hawleyville. It forms the bed rock over large parts of Litchfield, Bethlehem, Washington, Roxbury, Southbury, and Bridgewater. The rock is everywhere mica schist of definable character, but exhibits great variation in texture, composition, and field appearance. Its aspect has been rendered still more complicated by the intrusion of igneous rock on a large and a small scale. Where least affected by intrusion, the rock appears as a highly fissile schist. The planes of schistosity are determined by plates of muscovite and biotite in overlapping crystals or irregular intergrowth. The mica varies in size from flakes an inch or more in diameter to minute films or threads visible only under the microscope. In color it ranges from clear metallic muscovite in West Granby, to a black biotite mixed with graphite farther to the south. Sericite and chlorite often replace biotite. Garnets are almost constantly present, and locally occur in such quantities as to be of commercial value. Garnet crystals of the size of walnuts are occasionally observed in Roxbury and Washington. The local development of unusual quantities of this mineral in large crystals is believed to be due to local deformation along special structural lines. Staurolite crystals from an inch to two inches in length are also locally developed. Cyanite is scattered sparingly throughout the entire extent of the schist, and in places becomes the chief constituent of the rock. Next to mica and garnet, cyanite is the leading metamorphic mineral in the Hartland (Hoosac) schist, and occasionally occurs in Litchfield, New Hartford, and Barkhamsted, in crystals from two to three inches long. In places the porphyritic structure is developed, and large crystals of feldspar are closely wrapped about with films of mica. As may be seen in the railroad cut at Satan's Kingdom, the Hartland (Hoosac) schist is almost never free from quartzose and feldspathic impregnation, but its amount and character vary widely. Such impregnation may be caused by granitic injection, in which case the rock closely resembles a biotite gneiss. The granite may occur along the plains of foliation, as bands and lenses from a few inches to

one hundred feet in length. Basic intrusions are found throughout the schist, and in places, as in southeast Wolcott, form prominent beds over wide areas. Amphibolite is the common dark colored intrusive, and has the gneissoid and schistose characters of similar intrusions in the Becket gneiss. Pyroxene schists and eclogite schists also occur as lenses, layers, and areas of irregular shape. Granites, usually with pink feldspar, and pegmatites, and rarely quartz veins, are the latest intrusions in the Hartland, and are arranged either parallel to the planes of foliation or cutting across them. Part, at least, of the pegmatites are later than the metamorphic structures. The aggregate number of the later granitic and pegmatitic intrusions is very large. In the railroad cut on the south side of the gorge at Satan's Kingdom, where the rock wall is exposed for 1,700 feet, there are seven granitic layers with a combined width of 860 feet, besides several smaller seams. The granitic and pegmatitic intrusions are so numerous and of so small size that no attempt has been made to map them individually. One marked feature of the granitic and pegmatitic intrusions is the increase in the amount of cyanite, staurolite, and garnet near them. Occasionally there are nests and stringers of beautiful cyanite crystals within the pegmatite itself.

No fossils have been found in the Hartland (Hoosac) schist, and there is much uncertainty regarding its stratigraphic position. Whatever evidence exists on this point comes from a study of areas west and north of the state. Professors Emerson and Wolff conclude that the Hoosac schist is equivalent to the Berkshire schist of western Massachusetts, and this in turn has been shown to be equivalent to the Hudson schist of New York; that is, of Upper Ordovician age. It is, however, entirely possible that the Hartland is a later formation than the Hudson schist, and it is perhaps of Silurian age. Until fossils are found, or reliable criteria are discovered which suffice to show the relative order of superposition, the place of the Hartland schist in the geological column can not be determined.

It is probable that the Hartland (Hoosac) schist was originally a series of sedimentary beds, largely argillaceous sandstones and shales, with occasional calcareous and highly silicious strata, perhaps like the sedimentaries of the Triassic areas. The great variety now exhibited in the schists is partly due to variation in the original sediments, and partly to the unequal amount of metamorphism and injection that has taken place as a result of pressure, heat, etc. The changes produced in this formation by metamorphism since deposition are very great. The quartz and calcite have been recrystallized, and some of the limestone has been further changed to hornblende schist. Much of the feldspar has been broken up into feldspar, quartz, and mica; and many secondary feldspar crystals have been formed and afterwards flattened and elongated. The argillaceous beds have been altered chiefly by growth of new mica, and this has progressed so far that schists are much more common than rocks with flaggy or slaty structure. Schistosity has been produced by a flattening of all crystals, and by the production of new flat minerals, especially biotite, muscovite, sericite, chlorite, and cyanite, arranged parallel with each other, thus producing planes of easy parting. The micas are often wrapped around larger crystals of feldspar, quartz, and garnet. Metamorphism has progressed so far that all the original structures have been destroyed and new ones developed. The schist beds show great profusion of complicated folds and crumplings* and minor faults which have no fixed relation to the original planes of sedimentation.

The Hartland (Hoosac) schist is a resistant rock and weathers slowly because of the relatively small amount of feldspar. Where the disintegration has proceeded far there remains a soil composed chiefly of mica and quartz grains. The planes of schistosity usually dip at high angles, so that a surface exposure exhibits only the edges of the schist planes, and a railroad or river section shows the layers to stand nearly on end. It is not possible to determine the

* See Plate IX, Fig. 2.

thickness of the schist even approximately, for there is no way to ascertain the amount of increase due to the repetition of beds by crumpling and faulting. This formation has been cut off by a fault on the east, while much has been removed by erosion on the west.

Waterbury Gneiss [6] is not a distinct geological formation, but a complex of schists, which have been intricately injected with granite and pegmatite and occasionally amphibolite, in endless variety, without regular arrangement. It is believed that the areas marked Waterbury gneiss in the towns of Naugatuck, Waterbury, Torrington, Middlebury, and elsewhere, were originally Hartland (Hoosac) schist, and that granitic intrusions and quartz veins have impregnated them to such an extent that their original condition is almost entirely concealed.

Milford Chlorite Schist [7].— With the exception of a small area about Woodmont, the Milford chlorite schist occupies the shore line from Stratford to West Haven, as a belt rarely over two miles in width. It forms a narrow band adjoining the Triassic in the town of Orange, and dies out in the Woodbridge Hills west of Dawson Lake. The prevailing rock is a greenish chlorite schist, varying in thickness and hardness. In places it is evenly foliated, elsewhere highly contorted, and presents on surface exposures a series of broken anticlines and synclines. Quartz is an important constituent of the formation, and occurs in seams, lenses, and veins; it is also distributed in minute particles throughout the schist. Small bands of impure serpentine are found in it at several localities. In places the rock is massive, with the schistose structure hardly at all developed. Where it assumes this character it consists largely of hornblende and feldspar and constitutes the labradioryte of Dana. Occasionally this more massive variety is porphyritic from the presence of crystals of labradorite. In the vicinity of the Maltby Lakes a typical schistose rock occurs, and with it a considerable amount of impure serpentine — a dark colored rock, clouded and banded with patches of green, yellowish white, and black. From a quarry formerly located at this place

large slabs were obtained and polished, specimens of which may be seen in the geological collections in Yale University. A similar quarry of "verd-antique marble," discovered two miles east of Milford in 1811, was worked for a short time. This "marble" differs in appearance from the Maltby Lake rock in being bluish, rather than yellowish green. In the quartz veins associated with the chlorite schist crystals of chalcopyrite have been found. The Milford chlorite schist is believed to have been originally a diorite or similar basic igneous rock with intrusions in the form of dikes. The entire mass was afterwards much metamorphosed, drawn out into lines, and a definite schistose structure given to it.

Orange Phyllite [8].— The Orange phyllite extends from Stratford to the east line of Bethany, forming the banks of the Housatonic River from near Derby to the Sound. In Orange and Woodbridge the formation attains a width of about six miles, and it dies out in the trap ridges near the southern line of Prospect. A small area occurs along the shore at Woodmont. The rock is a slate or phyllite, highly fissile, sericitic, and usually dotted with minute garnets. Toward the west it is much more micaceous, in places approaching mica schist in texture, and is also frequently feldspathic. The latter feature is so prominent in certain localities that the rock might well constitute a separate formation. This micaceous phase of the otherwise argillaceous phyllite forms a belt between the typical argillaceous rock and the Prospect gneiss, and is believed to be a contact zone in which the phyllite has been modified by injection of the igneous mass. In structure the Orange phyllite is commonly minutely folded and contorted, and is so traversed by joints that it breaks readily into small polygonal fragments. Generally it readily decomposes and forms a dark clayey loam. Quartz veins occur frequently; and large and small chunks, lenses, and fragments of quartz are almost universally found in the formation.

Beds of impure limestone or marble are interstratified with the more argillaceous beds in a number of places. An abandoned lime-kiln is located on Sargent's River, north of

Westville, where the calcareous rock stands at a high angle between layers of phyllite (hydromica schist of Dana). Minute cubes of pyrite and much mica in fine scales are found associated with calcite. The presence of pyrite together with calcite is favorable for rapid weathering, and the ledges are covered with a thick brown crust. The impurities in the limestone, especially the mica, render it unfit for the production of lime, and the quarry was therefore abandoned. Orange phyllite is believed to have been originally a shale, more or less calcareous. It has since been metamorphosed, but not to such an extent as to be converted into mica schist.

Prospect Porphyritic Gneiss [9].—The Prospect gneiss occupies a triangular area in the towns of Prospect, Cheshire, and Southington, limited eastward by the Triassic strata, and extending south as a belt of varying width through Derby, Huntington, and Stratford. The rock is well exposed along the line of the Middletown and Waterbury railway, near Prospect and Summit stations. Here its characteristics are well developed, and from this region have doubtless come many of the bowlders of "mosaic" gneiss distributed over the region between Cheshire and Bridgeport. Typical outcrops also occur along the Housatonic River at Shelton.

The formation consists of a light gray porphyritic gneiss. The gneissoid appearance is produced by bands of granular quartz and feldspar interbedded with layers composed chiefly of biotite. Muscovite, garnet, chlorite, zircon, and titanite occur with the more abundant constituents. Within the ground-mass formed of these minerals there are set larger crystals of feldspar, mostly orthoclase, white or pink in color, thus giving the gneiss a porphyritic structure. These phenocrysts vary from one-sixteenth of an inch to three inches in their longest diameter, are quite fresh and regular, and in nearly all cases show twinning structure. Besides the typical coarse porphyritic gneiss, there occur in this formation small areas of porphyritic granite with inconspicuous gneissoid development, and narrow bands of mica schist distributed unevenly and not attaining the prominence which these beds have in the Becket gneiss. Pegma-

tite is found but rarely. At its extreme northern limit the Prospect gneiss is prevailingly less porphyritic and more quartzose, and contains areas of intrusive basic rocks.

This formation is believed to have been originally a mass of porphyritic granite intruded into the Hartland (Hoosac) schist. No contacts are visible, however, and direct proof of the date and nature of the intrusion is not at hand. Metamorphic processes have converted the rock into a gneiss with planes of schistosity whose strike averages about N.25°E. The marked characters of the original rock were such that the changes induced by folding and metamorphic action are readily traced. The phenocrysts of orthoclase were originally set at various angles in a granite ground-mass. Some of these were so oriented as to resist effectively the metamorphic forces, and consequently they remain in their original condition, with the exception that they are somewhat flattened, crushed at the ends, and converted into microcline. The phenocrysts less favorably situated have been squeezed, broken, and rotated into parallelism with the planes of schistosity. In many instances the original crystal is represented by lenses and eyes of granular feldspar and quartz, and in extreme cases all traces of the crystal are lost in the general gneissoid structure of the ground-mass. Besides the granular bands produced by metamorphism of the quartz and feldspar of the original rock, much new biotite and garnet have been formed, and, in less amounts, the other minerals mentioned above. The mica is seen to wrap about the feldspar phenocrysts and to be closely adjusted to it. Because of the unequal amount of metamorphism the Prospect gneiss varies from porphyritic granite, through gneiss containing flattened nodules, to a rock in which so great crushing and rearrangement have taken place that it has become a feldspathic mica schist.

Prospect gneiss is not porphyritic throughout its whole extent. Its western extension assumes a typical granitic texture, and in places its gneissoid structure is not well developed. In fact, the differences between this gneiss and the

Danbury granodiorite-gneiss are not always evident, and it may be that the two formations are parts of one granitic intrusion.

Bristol Granite-gneiss [10].— This formation occupies an area of about fifteen square miles, mostly in the town of Bristol, from which it derives its name. Topographically it forms a basin surrounded by a rim of Hartland (Hoosac) schist, and seems to owe its relatively rapid erosion to the presence of iron compounds and a great amount of feldspar as compared with the schists. The formation consists of granite of varying texture and color, of gneisses and schists derived from the granite, and of hornblende gneiss and hornblende schist. Pegmatite in veins and lenses of considerable size occurs in the eastern part of the city of Bristol.

The typical Bristol granite-gneiss is light gray, with gneissoid structure more or less developed by the presence of layers of biotite; the more schistose layers have muscovite. Quartz, orthoclase, some oligoclase, andesine, and biotite are the chief components of the rock. Garnet is nearly always present, and in places rises to the rank of a principal mineral. Chlorite, zircon, hornblende, also muscovite in the more schistose layers, are present as accessory minerals. Chalcopyrite is scattered through the rock, and is accumulated in little bunches of crystals. It is probable that the copper minerals are from the same source as the copper found in small amounts along the western border of the Triassic, and formerly mined at a point three miles northeast of Bristol.

A noticeable feature of the granite-gneiss is the presence of rounded and lens-shaped eyes, made up of a zone of white, granular quartz-feldspar aggregate, inside which is a dark spot composed largely of garnet and chlorite. The iron compounds have gone into the centers by segregation. These eyes are from one-sixteenth of an inch to two inches in diameter, but within the granite are areas, ten to thirty feet in diameter, of black rock composed of hornblende, chlorite, and garnet, which may have had the same origin as the smaller spots. These larger chunks were evidently

formed before regional metamorphism took place, for the minerals of the gneiss have adjusted themselves to them by bending and shearing.

The heavy cover of drift and the prevalent metamorphism make it difficult to determine the range of variation within the rock and its relation to the Hartland (Hoosac) schist. The formation is believed to be intrusive, as indicated by the fact that the schist dips away from the granite and seems to be controlled by it in its metamorphism. Parts of the granite-gneiss are traced with some uncertainty into the schists. The latter near the contact are highly metamorphosed into filmy sericitic varieties, and contain an abundance of mica and tourmaline; the granite shows local variations into hornblende gneiss, occasionally containing epidote, all along the east and southwest border. Aplites and tourmaline-bearing pegmatites also occur near the border. The Bristol granite-gneiss is believed to have been an intruded mass within which basic areas formed by segregation, especially about the edges. The surrounding sedimentary rock suffered contact metamorphism; at a later period granite and sediments alike were affected by regional metamorphism produced by a series of earth movements. The granite suffered great changes during the metamorphism of the rock. Quartz was broken and recemented; feldspar developed into new crystals of feldspar, mica, and quartz; biotite and hornblende changed in part into chlorite. These minerals crystallized parallel to the planes of differential movement, thus producing schists and gneisses which vary in amount of schistosity from almost unaltered granite to extremely finely divided schists bearing little resemblance to the original rock.

Collinsville Granite-gneiss [11].— Within the towns of Avon and Canton is an area of granite-gneiss. It forms the flattened ridge between the Farmington River and Roaring Brook, and also the prominent peak of Mt. Horr north of Canton station. At Collinsville this formation is particularly well exposed, and has received its name from that village. As seen in the ledge the rock exhibits usually a

banded gneissic structure, but it is unevenly and irregularly developed. Two types appear intermingled without order:—a light gray, heavy-bedded rock, grading into massive granite; and a very dark gray to black variety which grades by imperceptible stages into even-banded hornblende gneiss and rarely into schistose phases. The light colored variety is finely crystalline, and, where it is distinctly banded, shows black lines of biotite running through the rock, as well as patches arranged along planes of schistosity or evenly distributed through the mass. Where minutely injected, the rock appears coarsely crystalline, often with pink feldspars. It consists of feldspar, largely orthoclase but with some microcline and oligoclase, quartz in irregular grains, biotite in shreds or groups of plates sometimes radially arranged. Besides these essential constituents, hornblende and garnet and muscovite are usually present in small amount, and zircon, titanite, and magnetite have been observed. Chlorite occurs in the more schistose forms. The darker varieties of gneiss are produced by the greater development of biotite in bands and patches, and the rock splits readily into even slabs from one inch to ten inches thick.

The areas of hornblendic gneiss vary in size from mere bands and lenses to masses several hundred feet in diameter. The schistosity is well developed, and the faces of layers show mats made of intertwined hornblende and biotite. The rock consists essentially of hornblende with some quartz and feldspar. Epidote, garnet, biotite, zoisite, and chlorite occur in greater or less abundance in nearly all the hornblende rocks. Magnetite and augite have also been observed. Some of the hornblende rocks near the border are abundantly garnetiferous.

Dikes and veins of fine-grained granite and coarser pegmatite occur in the Collinsville granite-gneiss. These vary in width from one-sixteenth of an inch to a hundred feet, and in places are abundant. In Collinsville, near the Central New England station, six such dikes may be seen in an outcrop 250 feet long. Some of these pegmatites and some quartz seams

follow the schistose structure in its minutest folds; but for the most part the pegmatite and granite intrusions are clearly younger than the gneiss, for they cut across it at various angles and send off stringers and dikes into the surrounding rock. These granitic intrusions are made up of feldspar, quartz, and biotite, with some rutile, less muscovite and chlorite, and smaller amounts of garnet and magnetite.

The Collinsville granite-gneiss is believed to be a mass intruded in the Hartland (Hoosac) schist, and to have gone through about the same changes as have been already explained for the Bristol granite-gneiss. The contact has not been observed; and, even if exposed, it would scarcely be recognizable, owing to the minor intrusions and the metamorphism. The exposures in the Farmington River at Unionville show schist wrapping closely around gneissoid granite, with marked differences in attitude and composition; and in general the schist is seen to have adjusted itself to the granite and to dip away from it. Somewhat greater metamorphism of the Hartland (Hoosac) is noticed near the border of the granite. Much folding and minor faulting has taken place in the granite-gneiss, and buckling and crumpling are observed, particularly along the Farmington River. The axes of the larger folds dip under the schist. Metamorphism has produced gneissoid structure in the granite by rearrangement of the original minerals and by the production of much new biotite. The more dioritic facies of the original rock is represented now by hornblende gneiss, and more intense metamorphism in parts has produced schists from these two types. Most of the original structure has been destroyed. Hornblende and plagioclase are so abundant in parts of the Collinsville granite-gneiss that the whole formation might be called a granodiorite-gneiss.

Brookfield Diorite [12].— An area of diorite extends from near New Milford southward to Brookfield Center with a length of about eight miles and a width of one mile. At Hawleyville occurs another area of irregular outline, and

a still larger area is found in Litchfield and Morris, northwest of Bantam Lake. Outcrops of amphibolite may be included in the Brookfield, as the two are difficult to distinguish in the field.

The diorite is usually massive, but shows also gneissoid and even schistose phases. Both light and dark types are present in this formation, the former containing much quartz, and in extreme cases containing no dark mineral except biotite. The darker variety shows an almost complete absence of quartz and the presence of dark hornblende or a mixture of hornblende and biotite. Phenocrysts of feldspar assume a prominent rôle in the darker rocks, giving a porphyritic appearance.

While the rock in general resembles in appearance a porphyritic granite, schistosity has been developed, especially around the borders of the mass, and injection has produced a banded effect, generally accompanied by the production of new minerals, especially sericite, garnet, and staurolite.

The Brookfield diorite is an igneous mass intruded into the quartzite and schists of this region, as is shown by the facts that the Poughquag quartzite has been intricately injected, and that fragments of the surrounding gneiss are found included in the diorite.

Danbury Granodiorite-gneiss* [13].—This rock has an extensive development in western Connecticut. The largest area extends from near Birmingham to Bethel, and from Sandy Hook nearly to Easton. Belts extend through New Fairfield, Weston, Westport, and Fairfield, and along the coast line for most of the distance between Darien and the New York boundary. Still other small areas occur as shown on the geological map.

The rock presents two important facies — a biotite granite, and a diorite in which hornblende becomes an important constituent and quartz is less prominent. The two grade into each other, although, speaking generally, more hornblende occurs in the Greenwich and Wilton areas and parts of Monroe than in the mass north of Danbury.

* See note on page 86.

The rock is prevailingly porphyritic, with pink or white phenocrysts of feldspar, closely crowded, often attaining a length of one to two inches. The ground-mass in which the larger feldspar crystals are set consists essentially of two varieties of feldspar, quartz, and biotite or hornblende or both.

Metamorphism has produced gneissoid structures within the Danbury granodiorite. Usually the planes of foliation are some distance apart, thus giving the rock a massive appearance, and allowing large blocks to be quarried. In the vicinity of Greenwich the hornblendic variety is very fissile, and splits readily into even slabs suitable for curbing. The phenocrysts have been crushed in places and drawn out in lenses or eyes, thus producing an " augen " structure similar to that seen in the Glastonbury granite-gneiss. Where the rock has been more severely metamorphosed it passes into a hornblende-mica gneiss or even into a schist.

Granitic and pegmatitic injection has played a part in giving the final appearance to the rock, and makes it difficult to draw satisfactory boundary lines between this formation and the granites.

The Danbury granodiorite-gneiss is igneous in origin, and was intruded prior to the time when metamorphic action converted igneous and sedimentary rocks alike into gneiss and schist.

Thomaston Granite-gneiss [14].— This name is given to a number of masses of gneissoid granite, some of which are of considerable size. The larger tracts occur in Thomaston, Goshen, Weston, Westport, New Canaan, and Waterbury, while smaller masses and dikes cutting other formations are widely distributed. Foliation has been quite unevenly developed in the Thomaston granite-gneiss, and the rock accordingly varies in structure from almost massive granite to distinctly schistose phases. " Where least metamorphosed, as at the Plymouth quarry at Thomaston, and at localities on Candlewood Mountain, the rock is remarkably white in color, has a medium grain, and is flecked by numerous small scales of mica (biotite). The white base of the

rock is made up of about equal parts of a white feldspar (microcline) and quartz. Locally, as in the Wilton area, it is distinctly porphyritic, with phenocrysts of microcline, which sometimes reach one-half an inch in length. Examined in thin sections, with the aid of the microscope, the rock is found to be almost wholly composed of microcline, quartz, and biotite, with minute quantities of zircon and apatite. The gneissose varieties, such as the 'granite' quarried at Mine Hill in Roxbury, have marked secondary foliation, and a silvery mica has been extensively developed in membranes which cover the planes of foliation. This mica is often present in excess of the biotite. The latter mineral appears, however, in these varieties of the rock, in the same uniformly distributed equidimensional flecks which are characteristic of the massive varieties. The microcline of the gneissose varieties is further shown by the examination to be crushed and even granulated." *

That the Thomaston granite-gneiss is of igneous origin is shown by the fact that it so often occurs as dikes, and that fragments of other rocks are included within it. Similar evidence is afforded by the development of the epidote as a contact mineral. It is largely due to the injection of this granite-gneiss that certain gneisses like the Becket have developed locally such a decided banded structure. For the same reason it is very difficult in certain areas to distinguish the Becket and other gneisses from the Berkshire and Hartland schists.

Pegmatite.—As explained on page 71, pegmatite is essentially a giant granite, the individual crystals of which may reach the dimensions of a foot or more. Rock of this type occurs commonly throughout the western crystallines, in dikes or veins of small width compared with their length. Whether these are to be considered as dikes or veins depends upon the idea of their method of origin. Some of them are doubtless true veins in which the material has been deposited from heated waters; others are pretty clearly offshoots from granitic masses; and, as might be expected,

* W. H. Hobbs.

there is every gradation between the two types. Pegmatite is most abundant near granite areas, and is particularly prominent in the knotted variety of the Berkshire schist. In addition to the dikes and veins, two larger areas of pegmatite, situated respectively in the vicinity of Plymouth and Bethlehem, are doubtless parts of still larger deep-seated masses. Where pegmatite is abundant, the topography shows numerous white knobs. In composition the rock consists of feldspar (microcline, orthoclase, and albite), quartz, muscovite, biotite, and a number of accessory minerals, for example beryl, tourmaline, garnet, magnetite. In the larger pegmatite areas feldspar and quartz often occur intergrown to form graphic granite, and the constituent minerals attain a length of several inches. Pegmatite is apparently the last intrusion in the western crystalline rocks, as shown by the fact that dikes of this material intersect the granite-gneisses, which in turn cut the other formations of the region.

Litchfield Norite.— Certain dark gray rocks forming parts of Mt. Prospect, near Litchfield, have been called by Professor Hobbs Litchfield norite. This rock does not form large masses, but is found associated with granodiorite, diorite, and amphibolite. The area is not shown on the geologic map. Norite consists typically of plagioclase and orthorhombic pyroxene, usually hypersthene. In the Litchfield rock the feldspar is prevailingly labradorite; and, in addition to hypersthene, green hornblende and biotite are the most prominent constituents. Chalcopyrite and nickeliferous pyrrhotite are found in the less feldspathic parts of the norite. The presence of these minerals is responsible for the numerous unsuccessful attempts to secure nickel in commercial quantities at Mt. Prospect. As regards texture, the rocks are usually granitic, rarely porphyritic, and vary from fairly fine-grained rocks to those composed of crystals averaging one-fourth of an inch in diameter. Analyses of types of this rock, made in the laboratory of the United States Geological Survey, and published in Bulletin 228, show a wide variation in composition. "All the types of norite,

hornblende norite, mica-hornblende norite, mica diorite, hornblende-mica diorite, hornblende diorite, hornblendite, hornblende saxonite, hypersthenite, and lherzolite are found." *

The norite is of igneous origin, and its many varieties are largely due to differentiation during the process of cooling.

Amphibolite [38].— Distributed irregularly over the area occupied by the ancient crystalline rocks are dikes, lenses, and irregular masses of amphibolite. In nearly all cases this rock has a distinctly gneissoid structure, and is composed in large part of porphyritic feldspar and green hornblende. There is also a subordinate amount of quartz. The more massive types of amphibolite present a dark green base, mottled by areas of white feldspar occasionally reaching a diameter of an eighth of an inch. In favorable localities these feldspars are drawn out into lines. Where the rock is distinctly a hornblende gneiss, it is made up of alternating bands of feldspar and green hornblende. Locally, as in East Litchfield and Canton, garnet is developed, and near Bakersville and Collinsville the rock contains considerable greenish yellow epidote. Portions of the amphibolite are metamorphosed lenses of impure limestone, but in most cases the probability of its igneous origin is strong. It occurs distinctly as dikes, and its composition and texture are exactly those of a metamorphosed hornblende diorite. The amphibolite is older than the intrusive granites in the crystallines, as shown by the fact that dikes of the latter cut the former. Further, the fact that the amphibolite is interfolded with the Becket gneiss, Hartland (Hoosac) schist, etc., shows that its intrusion must have preceded the deformation which produced the major part of the metamorphism in this region.

Hornblendite, Soapstone, etc.— In addition to the amphibolite, there are small areas of basic rocks in western Connecticut which are related in a general way to the peridotites and pyroxenites. Among these are the areas of

* W. H. Hobbs.

hornblendite one mile north of West Cornwall station, two and one-half miles south of Still River, and at South Norfolk; and areas of soapstone and associated rocks three miles west of Torrington, a mile and one-half south of Bakersville, one mile north of Pleasant Valley, two and one-half miles south of New Hartford. Bowlders of soapstone, called locally " cotton rock ", are found between Bristol and Hartland. When fresh, these soapstones consist of actinolite or tremolite with more or less greenish brown hornblende and biotite. The soapstone contains anthophyllite or tremolite, talc, and serpentine. The latter mineral occurs both massive and fibrous (chrysotile, often called asbestus).

Diabase Dikes [39].— Certain dikes of dark colored igneous rocks occur in the crystallines of western Connecticut, which are unlike the amphibolites. They are dikes of diabase forming two more or less interrupted narrow bands, one extending from Fairfield to the north line of Derby, and the other through the towns of Orange and Woodbridge. In most places the dikes constitute ridges or small elevations in the surrounding metamorphic rocks, but occasionally they have no distinct topographic development and are recognized only by their composition and texture.

In surface appearance the rock is quite uniform, a dark blue, firm stone, differing in no essential particular from the trap of the Connecticut Valley region. The material composing the dikes consists principally of labradorite and pyroxene; it is broken by faults and joints, but does not show traces of regional metamorphism. On the other hand, the schists and gneisses into which the diabase is intruded are somewhat altered and baked. The unchanged diabase masses are believed to be of Triassic age, and thus are much younger than any other formation represented in the Western Highland of Connecticut. Like the trap rocks found elsewhere, these dikes furnish excellent material for road metal.

GEOLOGICAL FORMATIONS OF THE EASTERN HIGHLAND.

All of the state of Connecticut east of a line extending from Lighthouse Point, New Haven, to Somers, is made up of ancient crystalline rocks, nearly all of which have been affected by intense regional metamorphism. The formations in this section of the state have not been so carefully studied as those west of the Triassic area, and many of the statements regarding them are to be considered preliminary and subject to radical revision. In some cases the boundaries of the formations have been of necessity arbitrarily drawn, because the rocks seem to grade into one another, and yet to present such differences as to make it worth while to give them separate names.

The geological formations occurring in the Eastern Highland may be summarized as follows:—The Monson and Branford granite-gneisses, and the Mamacoke gneiss are probably igneous in origin and of very great age, and may represent pre-Cambrian masses. The Glastonbury granite-gneiss is of uncertain origin. The Bolton, Brimfield, and Woodstock schists, Pomfret phyllite, Plainfield and Scotland schists, and Putnam gneiss are doubtless the metamorphic equivalents of sedimentary strata of varying composition. The relation of these sediments to the igneous gneisses has not been made out, and there is practically no evidence in the field which determines the position of these formations in the time scale. The discovery of fossils of the Carboniferous period in the Worcester phyllite, which is probably the equivalent of the Pomfret phyllite, suggests a late Paleozoic age for most of the schists east of the Connecticut River. This view is strengthened by the evidence presented by the geological formations of central Massachusetts, where they have been studied by Professors Emerson and Perry. However, there is great similarity between the Bolton schist and the Hartland (Hoosac) schist; between the Woodstock and Plainfield quartz schists and the Poughquag quartzite; and between the Brimfield and the Berkshire schist. It is not at all impossible that more extended investigations may reveal evidence that the meta-

morphic rocks of the Western Highland are related to those of the Eastern Highland in time as well as in lithologic character. No organic remains have been found in the crystalline rocks of eastern Connecticut, and so long as fossil evidence is lacking no definite statements can be made regarding the stratigraphic position of the different formations. The Eastford, Sterling, Canterbury, Maromas, Haddam, Stony Creek, Lyme, and New London granite-gneisses, and the Preston gabbro-diorite, are intrusions in earlier strata; but were intruded before the time of the metamorphism that reconstructed the rocks of the entire state, and are accordingly much modified by the development of gneissoid and schistose features. The Hebron gneiss and the Middletown gneiss are of uncertain origin; the Willimantic gneiss is merely a more injected phase of the Hebron. Pegmatite and amphibolite are found cutting all of the formations mentioned above, and occasionally small lenses of limestone are found. The Westerly granite with its various types in the southeastern part of the state is later than the pegmatite, and is therefore the latest of all the formations, with the exception of dikes of diabase, probably of Triassic age, which extend in broken lines from the Sound to the Massachusetts border.

Glastonbury Granite-gneiss * [15].— The Glastonbury granite-gneiss occupies an area extending from the north line of the state in Somers and Stafford to Portland, with a width varying from one and one-half miles at Vernon to about four and one-half miles in Glastonbury. It is bordered on the east by the Bolton schist; and throughout the greater part of its extent forms the eastern border of the Triassic sandstone, from which it is everywhere separated by faults. The Glastonbury granite-gneiss extends into

* For data regarding the formations in the vicinity of Middletown the Connecticut Survey is indebted to Professor L. G. Westgate, who made geological investigations in this region at various times from 1896 to 1899. In 1900 Professor Westgate served with Professor Gregory on the U. S. Geological Survey, and presented an unpublished report, parts of which are incorporated in the present work in the descriptions of the following formations: — Glastonbury granite-gneiss, Bolton schist, Monson granite-gneiss, Middletown gneiss, Maromas granite-gneiss.

Massachusetts, and is the equivalent of the Wilbraham gneiss of Emerson.

Topographically this formation constitutes highlands throughout its extent, forming the ridges which are so prominent east of Hazardville, Rockville, Manchester, and Glastonbury. At Sandstone Mountain in Somers the rock attains an elevation of six hundred feet, and is scarcely less elevated through a large part of Glastonbury. Roughly speaking, the area may be divided into two parts — a broad western portion, decidedly gneissoid and usually dark colored, with a large quantity of biotite and hornblende; a narrower eastern portion, more granitic, and in places reaching the massiveness of a true granite.

"The more granitic facies of the Glastonbury gneiss is shown in exposures on the hill north of Great Hill Pond. Outcrops are abundant along the road at the top of the hill, and a small quarry has been opened in the woods east. The rock in the quarry is a quite massive, medium-grained biotite-granite, with scattered areas of quartz and feldspar, the latter sometimes approaching crystal form, while the main part of the rock is an aggregate of smaller quartz and feldspar grains." *

The larger part of the Glastonbury gneiss, however, is very different in its typical development from the rock which has just been described. As seen in the abundant exposures west of the Portland reservoir, it is a dark, well foliated, almost schistose gneiss, of fine grain, which on the cleavage surface shows alternating patches of black biotite and white feldspar. An examination with the lens shows minute yellow-green grains of epidote scattered among the feldspar aggregates, or more abundantly associated with the biotite. The epidote does not seem to be derived from the decomposition of any elements of the rock, for all are remarkably fresh. The presence of biotite and hornblende, arranged in parallelism with aggregates of feldspar, gives a distinct foliation and banding to the rock. Quartz is abundant, and orthoclase, microcline, plagioclase, titanite, and

* L. G. Westgate.

apatite occur. When numerous outcrops in this region are examined, it is evident that there is no sudden break between the gneissoid and massive varieties of this formation, but that they grade into each other.

This gneissoid type of rock prevails throughout the larger part of the area. The strong foliation, the abundance of biotite and hornblende, and the almost universal presence of epidote in small grains, distinguish this rock from the more granitic type to the east. Towards the west side of the Glastonbury area the rock is apt to be darker and more foliated, because of the larger amount of biotite and hornblende present. This more schistose variety forms the hills southeast of Glastonbury, and occurs in the bed of Roaring Brook in South Glastonbury. At this latter locality the rock is a very schistose granulitic gneiss, with lenticular masses of feldspar parallel to the foliation (the so-called "augen"), and containing flattened lenses or patches (technically called "schlieren") of darker material up to a foot or more in length. The rock has very much the appearance of having been crushed, but it is rare to find under the microscope clear evidence that crushing has taken place. "It is not uncommon, especially in the northern part of the area, to find outcrops of augen-gneiss associated with this western facies of the Glastonbury gneiss. As has already been indicated, the schistose variety in Roaring Brook is an augen-gneiss. These augen, pink or white in color, are generally granulitic aggregates of feldspar; but sometimes, especially further up the brook, they are sub-porphyritic feldspars. The augen aggregates are often drawn out at their ends into narrow lines, which run in among the micaceous portions of the rock." *

The more massive variety of this gneiss is seen in the small quarries north of East Glastonbury. The rock here is a light colored, fine-grained biotite gneiss or granite, which sometimes is quarried in blocks two or three feet in thickness, with no sign of a parting. Some bands are

* L. G. Westgate.

denser, with reddish feldspars, and approach an augen-gneiss. Schlieren occur, oval or lenticular, or sometimes drawn out parallel to the foliation. A section of one of the schlieren shows a much larger proportion of biotite than appears in the main part of the rock, and abundant epidote, in which respects it resembles the more foliated varieties of this formation. Another quarry occurs in this more massive gneiss three-quarters of a mile north of the village. The rock is a light gray, porphyritic, granitic gneiss. It is rather thick-bedded, and would make good curbing. The porphyritic feldspars sometimes reach a length of an inch, are single crystals or Carlsbad twins, and lie roughly parallel with the bedding. The rock is a foliated gneiss and contains epidote. Under the microscope the feldspars of the porphyritic areas do not show the same freshness as the rest of the rock. Epidote often holds its form against the biotite, and does not seem to be of secondary origin. It is commonly found grouped towards the center of the plagioclase grains, is rare in the microcline, and is not found in the quartz.

Thus in general the Glastonbury gneiss has "a double character — a granitic biotite gneiss or a biotite granite in a narrow band along its eastern margin; a darker, well-foliated gneiss with biotite, hornblende, and epidote in the remainder of the area. But this foliated gneiss becomes sometimes near the margin almost a schist; and, again, at localities well within the margin, quite massive; and both massive and schistose phases sometimes become augen-gneiss." *

Near the boundary between the Triassic strata and the Glastonbury granite-gneiss, the rock often appears as a rusty micaceous gneiss that has evidently undergone crushing. In places it becomes highly schistose, and contains sericite and biotite largely altered to chlorite, with a number of accessory minerals. It is believed by Professor Westgate that this facies of the Glastonbury gneiss is due to the movements connected with the faulting and deformation of the belt along the Triassic border.

* L. G. Westgate.

"In regard to the origin of the Glastonbury gneiss, there is strong indication that it is in large part igneous; and this applies both to the more massive eastern portion, and the more gneissic variety on the west. The former, in its outcrops in the quarry north of Great Hill, and in numerous bowlders scattered over the area to the south, reaches a massive character typical of a granite. The general and sometimes very marked foliation of the western part of the area certainly does not at first suggest an igneous rock; yet all intermediate steps can be found between this and the massive granite to the east. Within the area of well foliated gneiss, bands of more massive augen-gneiss are found, very similar to the augen-gneiss of the Maromas area, which is in all probability of igneous origin. Again, the presence of dark patches or schlieren is a strong evidence of its igneous origin. These are found, as has already been pointed out, in the most schistose facies of the gneiss, as seen in the bed of Roaring Brook in South Glastonbury, and they are found in the more massive facies, as illustrated at the East Glastonbury quarries [and at other localities]. Whether such dark inclusions are metamorphosed and melted masses of schist, or are basic segregations formed in the rock previous to solidification, is immaterial as to their bearing on the origin of the rock. In either case they are inexplicable on the supposition of its sedimentary origin." *

The igneous origin of the Glastonbury granite-gneiss is further indicated by the contact phenomena exhibited along its borders. At the top of Collins Hill in Portland the contact between the gneiss and the Bolton schist "is sharply defined, and the gneiss and schist are perfectly distinct. The line of the contact is irregular, and inclusions of schist [similar to the Bolton] occur at several points in the gneiss. This same biotite gneiss occurs for a short distance down the hill to the east, and can be followed north along the line of contact for a quarter-mile." * The contact phenomena shown at this locality suggest an eruptive

* L. G. Westgate.

origin, but the evidence from the field as a whole is inconclusive.

Bolton Schist [16].— The Bolton schist occurs as a belt rarely exceeding a mile in width, and extending from the northern line of the State at Stafford to Great Hill, which forms the boundary between Portland and Chatham. At Cobalt the belt divides, and sends one arm to the northwest, wrapping about the Glastonbury gneiss, and another arm to the southeast, extending a little beyond the Connecticut River. A partially detached area of Bolton schist extends along the eastern border of the Triassic from Portland to Lake Quonnipaug in Guilford.

Throughout its entire extent the Bolton schist is a marked topographic feature, and constitutes a high ridge or series of ridges. The belt from Great Hill to West Stafford is almost a continuous ridge, rarely under five hundred feet in elevation, and cut through by streams at West Stafford, Bolton Notch, and Dark Hollow. The southern belt has its culminating points in the White Rocks and Chestnut Mountain.

The Bolton schist is a silvery sericite schist showing considerable variation in character, and includes gneissoid bands as well as beds of quartzite and marble. Besides feldspar, quartz, muscovite, and sericite, the rock contains biotite, garnet, and staurolite in abundance. In places the schist contains the latter minerals in such quantity that it might be properly classed as garnet schist or staurolite schist. Magnetite, graphite, fibrolite, pyroxene, rutile, pyrite, and chlorite also occur. Any one or more of these minerals may be absent from a given outcrop.

One of the best exposures of this rock is along a road through the ravine which cuts across the schist range, about a mile north of the northeast corner of Middlesex County. On the west the rock is a silvery sericite schist, everywhere containing abundant garnets, and generally small prisms of staurolite. Farther to the east, and beyond the ravine, the Bolton schist is represented along the road by a dark fine-grained biotite gneiss, the minute brown biotite flakes of

which give a distinct purplish color to the sandy or gneissic facies of the Bolton, and indicate its gradation into the Hebron gneiss. Two miles southwest the silvery schist again appears. Garnets and staurolite prisms are abundant, and the microscope reveals much magnetite dust, and abundant films of sericite, curving around and between the quartz, garnet, and staurolite, and also shows an equal amount of brown biotite in smaller, usually unbent flakes. This same rock is exposed in numerous outcrops along the east side of the range, west of Lake Pocotopaug. It is here that staurolite occurs in its largest development, the prisms reaching two or three inches in length, and a half-inch in their longest diagonal. The Bolton schist along its eastern border near the north end of Lake Pocotopaug, and in a corresponding position farther north, is prevailingly a fine-grained biotite gneiss, passing into a biotite schist. Staurolite schist again occurs along the south face of Great Hill, but it here lacks the silvery sericitic character it has farther north, and becomes a sandier and more gneissic biotite schist, with garnet and staurolite. The schist along the west side of the Bolton belt is not always staurolitic; garnets are almost invariably present, but staurolite, while abundantly present in certain exposures, is absent in many others.

Good exposures of the Bolton schist occur also along the Air Line railroad for more than a mile east of Cobalt station. Immediately at the station the rock is a medium-grained biotite schist, the mica laminæ often closely crumpled, and alternating with thin layers of quartz. Weathered outcrops show the rusty appearance characteristic of the schist. The rock exposed in the railroad cut a mile and a quarter east of the station, is a fine-grained schist, containing beds of gneiss. Its color is gray when freshly exposed but becomes rusty on weathered surfaces. The abundant biotite is often bleached, and forms wavy laminæ about knots of quartz. Small grains of pyrite are found in association with the other minerals. The rock is grayer and less silvery than the staurolite schist found farther north. The gneissic bands are also fine-grained, and

the small scattered biotite flakes are hardly numerous enough to produce a distinct foliation in a hand specimen. Small garnets are present. The gneiss occurs in beds of greater or less thickness, interbedded with the schist, and all are evidently parts of the same formation. In some cases the gneissic bands more or less completely lose their biotite, and a quartzose type of rock is produced identical with phases of the Hebron gneiss, and closely resembling a quartzite.*

It is interesting to note that this section, showing silvery schist with garnet and often staurolite, followed by alternating beds of schist and quartzose gneiss, is reproduced in the section at Bolton Notch, and at points still farther north towards the state line. The sandy quartzose layers, however, attain, in the more northern localities, a development and a character of their own, which are lacking in the corresponding rock of the south.

The rock exposed at Diamond Lake in Glastonbury, in Bolton, in Tolland, and farther north, is much more prevailingly sericitic, and oftentimes takes on a graphitic appearance, becoming dark and lead-colored. At a number of points near the northwest border of the formation the schist is much shattered and seamed with quartz, dark gray in color, and finely granular in texture, instead of presenting distinct foliation surfaces covered with films of mica. In these places the rock is closely folded and otherwise distorted. This peculiar facies of the schist has been ascribed to mechanical movements associated with the faults along the border of the crystalline area.†

At a number of localities in the Bolton schist, as shown in the cut on the Air Line Division northwest of Job's Pond, there occur bands and lenses of impure limestone. These bands are interbedded with the schist, and have taken part in the faulting to which the schist in general has been subjected. Wherever the limestone occurs it is fine-grained, grayish in color, and contains light greenish patches of

* The above paragraph and the one preceding are taken substantially, though not *verbatim*, from the unpublished report of L. G. Westgate.

† L. G. Westgate.

pyroxene. Usually more or less mica occurs with the limestone, and at Bolton Mountain and elsewhere it grades into a calcareous mica slate.

Quartzite in the Bolton Schist.— Bands of quartzite and quartz schist occur in the Bolton formation; but, although these bands are of considerable extent and characteristic, it does not seem practicable to treat them as a distinct formation. The quartzite shows a wide range, from almost pure quartz like that of veins to quartzose mica schist. In the southern part of the area it forms the summit of Great Hill, and has been traced northward along the range for three miles. Towards the north it becomes thinner, is a less marked topographic feature, and has not been identified in place beyond a point southeast of Meshomasic Mountain. East of the quartzite, which occupies the summit of the range, occurs the typical Bolton schist. To the west, wherever exposures are found (and they are rare, and never within a half-mile of the quartzite), the rock is a granite-gneiss. "Quartzite and schist alike dip to the west, so that, unless we are here dealing with an overturned fold, the quartzite is the uppermost member of the Bolton schist which is exposed in the range. The rock is sometimes a massive quartzite, with small quantities of muscovite in minute scattered grains. Then, with an increase of muscovite, the rock becomes foliated and in extreme cases schistose. Constant alternations occur in the ledges, between the more massive and more schistose varieties. At a few points the rock takes on an appearance which suggests a conglomerate."* Toward the north line of the state the quartzite is much more schistose in structure, and is nearly always micaceous. Besides the minerals mentioned above, pyroxene, magnetite, rutile, and rarely chlorite, occur in the rock.

At a point west of Pocotopaug Lake the rock has been quarried on a small scale for whetstones. Other quarries were formerly worked in Bolton and West Stafford. The abandoned quarry at Bolton Mountain was at one time

* L. G. Westgate.

famous for its flagstones, which may be now seen on the streets of the larger Connecticut cities.

Lenses and dikes of amphibolite are so abundant in the eastern part of the Bolton schist that they were considered by Percival as a separate formation. Usually the amphibolite is schistose, but in places it is gneissoid, and generally contains pyroxene, epidote, and chlorite.

Pegmatite occurs, usually in narrow veins distributed haphazard throughout the schist; but at the White Rocks, east of Middletown, it forms a large part of the outcrop, and varies from a white granular rock to a giant granite with crystals of feldspar several inches in length.

The general dip of the Bolton schist is towards the west, and throughout its extent it is much folded or crumpled. It is believed to be of sedimentary origin, and to be the metamorphosed equivalent of a stratified series consisting of sandstones, shales, and some limestone. Its sedimentary character is indicated by its great variation in field appearance and in mineralogical and chemical composition, as well as by the presence of marble, quartzite, and graphite. In many respects this formation resembles the Hartland (Hoosac) schist. The Bolton schist doubtless had originally much greater extent than at present, and was the country rock into which the Maromas, and probably the Glastonbury, gneiss was intruded. No fossils have been found in it nor in any adjoining rocks (except the Triassic sandstones), and it is therefore impossible to assign the formation to a definite place in the time scale.

Monson Granite-gneiss [17].— Bordering the Bolton schist on the east is a band of gneiss extending in a southwesterly direction from the northern boundary nearly across the state. Northward it extends into Massachusetts, and the rock is extensively quarried in the town of Monson, from which locality the entire formation derives its name. The rock is exposed in ledges in many localities, and forms a large part of the bowlders which are strewn so abundantly in the valley of the Willimantic River, from the Massachusetts line southward. The best exposures of this rock

within the state are found in quarries along the Connecticut River. At Arnold's Station in the town of Haddam, quarries have long been worked on a high hill near the station, and the stone taken out has left a deep trench extending directly through the summit of the hill. The quarried rock has been used for curbs and block pavement. Where typically exposed, the rock is a fine-grained, dark gray, uniform biotite-hornblende gneiss, marked at short intervals by parallel seams of quartz with some biotite and hornblende, along which the rock is generally split in quarrying. This rock is somewhat darker than the darker variety quarried in Monson. Across the river at Haddam Neck several quarries have been opened on the hills facing the river. These quarries are not at present being worked. The rock here is gray, fine-grained gneiss, lighter in color than that at Arnold's. As seen in the quarries, it consists of alternate light and dark bands, which are nearly vertical, and parallel to which the foliation has been developed. Biotite is the most abundant dark constituent, and generally the only one, though in some cases hornblende is the more abundant mineral. Orthoclase and plagioclase, quartz, and garnet are present.

Where the rock is quarried, both north and south of the river, it is a uniform and generally rather light colored gneiss, and is not marked to any extent by the presence of intercalated bands of dark hornblendic gneiss or amphibolite. This would naturally be the case with those portions of the rock chosen for quarrying. Such bands of amphibolite are, however, quite characteristic of the gneiss belt as a whole, and there is scarcely an outcrop of any extent which does not show one or more of them. In many instances these amphibolites form narrow and distinctly foliated bands, parallel to the structure of the enclosing gneiss, but sometimes they cut across the foliation obliquely, and they are often of a massive character, which strongly indicates an eruptive origin; so that it is considered probable that most if not all of the amphibolite, which forms such a striking contrast to the light colored gneiss, is igneous.

The Monson gneiss is believed to be igneous in origin. Its uniformity of texture and composition over wide areas, and the absence of minerals distinctly characteristic of sedimentary rocks, testify to an original igneous mass. It is suggested that the bands of amphibolite and granite-gneiss, which make up this formation, have been developed by metamorphism from original masses formed by segregation when the rock was yet in a molten condition. This formation was formerly considered as of sedimentary origin, and has been described as a metamorphosed conglomerate.*

Brimfield Schist [18].— One of the largest sections of metamorphic rock in the eastern division of the ancient crystalline rocks is that occupied by the Brimfield schist, covering practically all the towns of Union, Ashford, and Willington, and large parts of Woodstock and Stafford. The formation extends northward into Massachusetts, and has received its name from the town of Brimfield in that state. Toward the southwest it extends to Bolton.

Throughout its whole extent this formation shows striking uniformity in the general character of the rocks. It contains numerous varieties, but all of them are peculiar to this area. Perhaps the most conspicuous feature of the Brimfield schist is its rusty color, caused by an abundance of disseminated grains of iron. The soil formed from it is generally reddish or yellowish in color. The typical Brimfield schist is a rusty, dark colored or purplish rock, showing great variation in the development of schistosity. The mica in the rock is in places white and silvery muscovite, but more commonly biotite, with a reddish or purplish tint. It may occur in flat crystals, or it may be drawn out into fibres. Garnets are generally abundant in the schist as well as in the subordinate bands of gneiss which occur with it. In addition to the mica and the usual feldspar and quartz, there occur also sillimanite and graphite. The sillimanite occurs in clumps, clusters, or sheaves, or in individual needles scattered throughout the rock, and forms one of the charac-

* Emerson, *Geology of Old Hampshire County, Massachusetts*, United States Geological Survey, Monograph XXIX.

teristic features of this formation. Graphite occurs in small fragments with metallic luster, and occasionally in sufficient abundance to attract a prospector. Abandoned "lead" mines are found in parts of Ashford, Union, and Mansfield, as well as farther north, in Massachusetts. The iron in the rock is so abundant that it has been mined in certain localities. Near Staffordville ore was taken out in some quantity between 1840 and 1850. Here the ore was of two varieties — the common bog iron ore, limonite; and a reddish or yellowish earth which came from the decomposition of rocks in place.

In certain belts extending in a north-south direction the Brimfield schist takes on a gneissoid character, doubtless due to enrichment by quartz and feldspar along the planes of foliation. So marked is this arrangement of the gneiss and schist that the formation may be considered as a series of alternating bands of schist and gneiss.

Beds of hornblende and of pyroxene occur in this formation; also thin beds of impure limestone; and in places pyrite becomes a prominent constituent, and has given the name of "sulphur rock" to certain ledges.

Brimfield schist is not markedly folded or crumpled, having in general a quite uniform schistose or slaty character. About the areas of intruded granite, however, the rock is often much crumpled. In such localities the schist is occasionally marked with knobs and little knots, which closely resemble similar structures in the Berkshire schist.

It is believed that the Brimfield schist is the metamorphosed equivalent of sediments prevailingly argillaceous, but including also sandy and calcareous beds. The part of the Brimfield included in Massachusetts is believed by Emerson and Perry to be of Carboniferous age, but as yet no evidence on this point has been found in Connecticut.

Eastford Granite-gneiss [19].— Extending through the towns of Woodstock and Eastford to Chaplin is an area of gneiss averaging a little over two miles in width. The rock in general is a light or dark gray gneiss, fine-grained, or in places even porphyritic. Lines of schistosity are well

developed, and only a very slight amount of folding or crumpling has taken place, so that the rock is suitable for quarrying. At the " ledges " near Eastford village the rock is a biotite-muscovite gneiss, light colored, and containing much quartz and feldspar arranged along definite lines. Perhaps the best exposures of this formation are in the southeast corner of Eastford, where considerable quarrying has been carried on in past years. Here the rock is distinctly gneissoid in parts, and in other parts it is massive, with a uniform texture and regular structure throughout. The differentiation into light and dark gray varieties is not a prominent characteristic in this section, but small flattened lenses of biotite give the rock much the same appearance as that possessed by the Monson gneiss. Like most of the gneisses in the state, this formation is cut by seams of granite and pegmatite, with an occasional bed of amphibolite. Both the granite and the amphibolite dikes are later in age than the country rock. The composition and texture of the Eastford granite-gneiss, as well as its field occurrence, suggest an igneous origin.

Woodstock Quartz Schist [20].— There are two areas of quartzose rock in the northeastern part of the state, named respectively the Woodstock and the Plainfield quartz schist. The Woodstock quartz schist extends through the eastern part of Woodstock, and continues southward through Pomfret, terminating near the western border of Hampton. This area is deeply covered by glacial deposits, and few outcrops have been located. In character the schist varies from an almost pure quartzite to a mica schist with abundant quartz grains. Near North Woodstock the schist is a purplish rock consisting of quartz, sericite, and muscovite, and varies in texture from a rock which is practically sandstone to a very micaceous or, rarely, a chloritic schist. In places hornblende in small green crystals is distributed generally through the rock, giving a greenish tint to certain layers. The Woodstock quartz schist is believed to represent sedimentary sandstones and clay rocks. The original quartz grains are now partly converted into crystals of

quartz, and the argillaceous material is now represented by the micas. Rarely calcareous bands occur. "Quinnebaug whetstones" were formerly quarried from the fine-grained quartzite. The continuation of the Woodstock quartz schist in Massachusetts has been separated into several distinct formations.

Pomfret Phyllite [21].— Skirting the eastern border of the Woodstock quartz schist, and extending south into Hampton, is a narrow belt of mica slate or phyllite. A detached area occurs in Bozrah and Franklin, and it is possible that the two are connected by a narrow band extending along the valley of Little River. Where typically developed, as in the northeastern part of Pomfret, the phyllite is well foliated, the foliation planes being made of minute flakes of mica, which give the rock a purplish tone and a silky luster. The rock of this type continued northward seems to be the equivalent of the "Worcester phyllite" of Perry and Emerson. In addition to the typical phyllite, this formation also exhibits distinctly schistose varieties, containing much muscovite in fairly large plates. This type is traversed in places by calcareous seams, with which hornblende crystals are associated. In places long fibrous minerals are arranged in sheaves and bunches along foliation surfaces in such a manner as to simulate fossils.

Putnam Gneiss [22].— Extending from the northeastern corner of the state down along the valley of the Quinnebaug River, and reaching beyond Norwich, is an area of gneiss quite unlike any other formation in the state. This is the Putnam gneiss, and is extremely variable in texture and sometimes in composition. The rock is made up of bands of schist, gneiss, quartzite, and igneous intrusions in such variety that it is possible to collect several unlike specimens within a distance of ten to fifteen feet across the strike. In texture the rock varies from a compact bluish black slate and quartzite, through fine, black schist, to coarse, gray, quartzose schist and feldspathic gneiss. The formation also includes beds of limestone, sheets of Sterling granite-gneiss and peg-

matite, amphibolite, and layers of a black granite porphyry. In composition the formation shows gradations from a hornblende-biotite schist (or sedimentary amphibolite?) with little or no feldspar, through a quartz-biotite schist and gneiss (or crystalline arkose?), to a quartzite.

In the eastern part of the area, principally in the towns of Preston and North Stonington, where detailed work has been done by Dr. G. F. Loughlin, there are two main varieties — a gray schist, often feldspathic, and a fine biotite-hornblende schist, both thoroughly injected with intrusive sheets and stringers of granite and pegmatite. The fine black schist evidently underlies the gray feldspathic variety, and, where it comes into contact with the Preston gabbro-diorite formation, has the appearance of hornstone. The alteration to hornstone doubtless took place before the metamorphism occurred which recrystallized all the rocks of this region.

A characteristic feature of a large part of the Putnam gneiss is well displayed near Moosup village and in the railroad cut west of Putnam. Here the rock has the appearance of a conglomerate, more or less crushed and drawn out into lines. When the apparent pebbles are examined, they are seen to consist of feldspar crystals or small areas of quartz and feldspar, about which biotite and hornblende have been closely wrapped. It thus forms a metamorphic pseudo-conglomerate. The "pebbles" are seen not to be regularly distributed along the planes of schistosity. The crystals forming the "pebbles" of this rock owe their origin to granitic intrusion or to injection by hot solutions which have added to the original rock material for the formation of feldspar. It appears on fuller investigation that the layers of "conglomerate" are metamorphosed sheets of granite porphyry.

A typical outcrop of Putnam gneiss exhibits bands of black hornblendic schist alternating with gray gneiss, and shows numerous granitic injections. Surface exposures usually have a brownish or greenish color due to the alteration of the black minerals.

In addition to layers of slate and quartzite, the Putnam

gneiss contains at several points limited beds of dolomitic marble or limestone. The most important of these localities are near the northwest corner of North Stonington, and on the east slope of Swantown Hill, where lime-kilns were once operated on a small scale. There was also a kiln located on Follyworks Brook, a little over a mile northeast of Preston City. The limestone is completely crystalline, and is accompanied by various minerals, such as actinolite, tremolite, titanite, biotite, and feldspar, that have developed from the impurities in the dolomite as a result of metamorphism.

Although the Putnam gneiss presents such marked variation in texture and composition, and presents at all points such complicated structures, yet it has been derived from simple sedimentary rocks deposited in horizontal strata, and doubtless containing fossils. The slate, the quartzite, the limestone, and the occasional presence of graphite in the black schist suggest a sedimentary origin, and the formation is believed to have consisted originally of beds of sand and mud and deposits of impure limestone. At some date later than the original deposition and prior to the Triassic, the strata have been greatly modified by two processes — igneous injection and regional metamorphism.

The rocks constituting the Putnam gneiss were injected by granitic sheets and dikes and by hot aqueous solutions and vapors. The intrusions seem in large part to be parallel to the bedding. The intrusions include dikes and sheets of Sterling granite-gneiss, varying from masses one hundred feet in thickness to the finest stringers; pegmatite veins, also varying much in size, running down in places to mere veinlets of quartz; and sheets of black granite porphyry, with the larger phenocrysts exceeding two inches in length. Associated with the black porphyry are sheets of sheared diorite or hornblende schist varying in width from ten feet to a fraction of an inch. The coarser-grained of these sheets are easily identified as intrusive; but, in the case of some of the finer-grained ones, field evidence alone is not sufficient to determine whether the rock is igneous, or a metamor-

phosed sediment containing large amounts of iron oxides, magnesia, lime, and silica.

The severe metamorphism which is so evident in the Putnam gneiss represents several stages, some preceding, others following or accompanying the granitic intrusion. Near the larger intrusive masses the shales have been converted into hornstones, or into slates, schists, and gneisses; the sandstones have become quartzites and schists; and the limestones are now represented by impure marble. Schistosity has been developed in the entire area, and the gneiss is so closely folded and contorted that the same bed may occur several times in one outcrop. The extreme plication and the frequent recurrence of beds, together with the great and constant variation in texture, make definite correlation practically impossible.

The age of the Putnam gneiss is unknown, and the data at hand are insufficient even to determine its local stratigraphic position. The evidence indicates that the Putnam underlies the Scotland schist. The two formations are conformable, and pass into each other without noticeable change. All the igneous rocks of this district occur as intrusions in the Putnam gneiss, and this formation is therefore older than the various dikes, sheets, pegmatite veins, and igneous masses found associated with it. The isolated outcrops of gray biotite gneiss occurring in the Sterling granite-gneiss may be remnants of the Putnam gneiss; and, if so, the formation was originally of much greater extent, reaching southward perhaps as far as Long Island Sound, and eastward into Rhode Island.

Plainfield Quartz Schist * [23].—A band of quartz schist similar to that in Woodstock extends from the northeast corner of Thompson southward through Killingly, Plainfield, and Griswold, east of Pachaug Pond, and into North

* The geological formations in southern Windham and in northern New London county have been studied by Dr. G. F. Loughlin. During the summer of 1904 Dr. Loughlin was assistant on the Connecticut Survey, and later undertook a special investigation of the Preston gabbro-diorite and adjoining formations. Through the kindness of Dr. Loughlin free use has been made of his notes and manuscript in preparing the descriptions of the rocks of that region, especially of the Plainfield quartz schist, the Sterling granite-gneiss, the Lantern Hill quartz rock, and the Preston gabbro-diorite.

Stonington, while a shorter band lies parallel to it in Voluntown as far south as Pendleton Hill, and is separated from the larger area by an intrusive mass of porphyritic granite. Throughout its entire extent the rock is highly quartzose, but varies in its texture from a finely divided quartz schist to an almost massive quartzite, and again to a dark colored rock resembling slate. The slaty variety occurs in the vicinity of Pachaug Pond, and is less resistant to the weather than the lighter colored rock which is typically exposed in northern Plainfield and at Pendleton Hill. Farther to the south the quartz schist becomes finer in texture and more resistant; and where it appears at Ashwillet, or better yet at Barnes Hill, the rock is so dense and silicious that it might be called a quartzitic hornstone.

South of Barnes Hill and Prentice Mountain, the quartzitic hornstone fades out into scattered outcrops, and is not found south of the northern end of Swantown Hill; but it is possible that a continuation of this formation is found in a small outcrop of hornstone with well developed slaty cleavage, about half a mile north of Lantern Hill.

Outcrops of the eastern band of the quartz schist are not found south of Pendleton Hill; but the location of sharp, angular bowlders is such as to prove its continuance southwestward to the northern border of Wyassup Lake; while outcrops west of the lake show a gradation from the light quartzitic rock to the coarser, gray quartz-biotite schist of the lower part of the Putnam series, which becomes lost in the Sterling granite-gneiss. Another noteworthy band of the quartz-biotite schist can be followed for two miles or more along the road running east from North Stonington village.

In certain localities feldspar occurs as a constituent of the quartz schist, giving the appearance of a fine arkose or even of a granite. In fact, through parts of Plainfield the distinction in the field between the quartz schist containing feldspar, and the fine, aplitic contact phase of the Sterling granite-gneiss, is very difficult, and the position of the boundary of these formations is accordingly uncertain.

As regards stratigraphic position, the Plainfield quartz schist seems to be part of a series which includes the Putnam gneiss. North of Lantern Hill the slaty hornstone schist grades into the fine, black schist of the Putnam gneiss series, which suggests a conformable relation between the two rocks. This relation is also shown in the vicinity of Pendleton Hill, where the quartz schist underlies the biotite schist, and again is underlain by a similar rock, giving rise to the belief that the Plainfield quartz schist, instead of being an independent formation, is only a prominent and clearly marked variation of the Putnam formation. The Plainfield quartz schist seems to lie near the base of the Putnam series, and to be the oldest sedimentary formation in this region. Additional evidence of its age is afforded by the fact that it contains intrusions of the Sterling granite-gneiss, sheets of granodiorite, and stringers from the Preston bathylith.

Sterling Granite-gneiss* [24].—The eastern border of the state from East Killingly southward is occupied by an area of granite-gneiss, which has a further extension northward through Rhode Island and Massachusetts. It also extends in an elongated area, between the Putnam and Mamacoke formations, through the extreme northern parts of Ledyard and Montville. The Sterling formation is made up of two distinct types: a porphyritic gneiss, with an abundance of biotite along the foliation planes; and an aplite, or a granite-gneiss practically free from mica. The porphyritic type is always highly gneissoid, and the phenocrysts are drawn out into lenticular forms. These phenocrysts are of pink feldspar, and in some places attain a considerable length; elsewhere they are scarcely distinguishable from the groundmass. In the latter case, the rock shades into a normal granite, which, as far as mineral composition goes, is intermediate between the porphyritic and the aplitic types.

The aplitic type is probably a later intrusion than the porphyritic and normal types, since fine aplite dikes or stringers are sometimes found cutting the porphyritic rock.

* See note on page 132.

While these dikes are fine-grained, the aplite often forms large masses showing a medium and sometimes even a coarse grain. These masses are best shown in northern Ledyard, North Stonington, and northeastern Griswold. The rock consists principally of quartz and feldspar, with frequent grains of magnetite, sometimes in fairly distinct octahedral crystals scattered evenly through the mass. Both biotite and muscovite may be present or absent, but biotite is almost never prominent. When biotite is present, the rock is usually rather fine-grained, and appears to grade into the normal type. Muscovite in considerable amount is practically limited to the outcrops of highly gneissoid and sheared rock — a condition which strongly suggests, for part of it at least, a secondary origin due to dynamic metamorphism. Though a gneissoid structure is always more or less developed in the aplite, the variety destitute of mica has often a massive appearance, especially when seen across the planes of foliation.

In certain places where pressure and shearing were particularly strong, the rock of both types is highly contorted, and even converted into a muscovite schist by the effect of pressure on the feldspar. These sheared places are often accompanied by segregations of quartz, which, in some instances, has probably developed at the expense of the feldspar. Both types are injected by pegmatite of the same general composition as the aplite; and in several places the typical pegmatite can be traced into veins of gray, rather smoky quartz, which branch and continue as veinlets in the granite.

The general color of the granite-gneiss is pink to red, although, in some regions, where exposed in fresh cuts and quarries, it is light to medium gray. The color depends largely on the oxidation of the iron in the feldspar, and on the amount of the mica present. The pink color in the phenocrysts of the porphyritic type, and of the feldspar of the aplitic and pegmatitic types is evidently original, for fresh exposures show just as high a color as the weathered outcrops; and, in places, the weathered surfaces have even

become whitened by conversion of the feldspar into kaolin. But, where the phenocrysts are not prominent, the pink color is evidently due to superficial oxidation, and is found only in weathered specimens. The unaltered rock in such cases is gray in color, as is well shown in the large quarry at Oneco in Sterling.

With the exception of pegmatite injections, the Sterling granite is free from intrusions, except in the vicinity of Long Island Sound. In the region from Westerly to Groton there are large dikes of fine Westerly granite, which is, or has been, quarried at several places. At Westerly, both the fine Westerly, and the Sterling, or "red Westerly," granite are quarried; but the amount of the Sterling granite is much less than that of the famous fine-grained Westerly.

That the Sterling granite-gneiss is of igneous origin is beyond a doubt, as both the porphyritic and the aplitic type show the characteristics of granitic masses. Furthermore, basic segregations or *schlieren*, which are further evidence of igneous origin, are often found in the quarries, drawn out in the plane of foliation; and still further proofs are found in the frequent occurrence of isolated massesof the older Putnam gneiss included in the granite, and in the abundance of sheets of Sterling granite-gneiss intruded into the Putnam formation, and diminishing in size the farther they extend from the parent mass. In fact, the Sterling granite-gneiss is believed to be a bathylith underlying a large section of eastern and southeastern Connecticut, and coming to the surface in a number of localities mapped separately as granite outcrops and hills. Whether or not the Sterling granite-gneiss is related to the Canterbury granite-gneiss or to any of the granite-gneisses along Long Island Sound is not yet definitely known; but intrusive sheets occur as far west as Norwich, if not farther, and the aplitic type has been traced westward across the Thames River and on into Salem.

Lantern Hill Quartz Rock [24a].— At Lantern Hill, North Stonington, occurs an enormous mass of quartz, showing itself topographically as a conspicuous elevation.

The range is 1,000 to 1,500 feet in width, and fully a mile in length, extending from the southern end of Long Hill to the relatively low hill north of Lantern Hill, and descending into the narrow east-west valley beyond. The summit of Lantern Hill rises 520 feet above the sea, and over 400 feet above the surrounding country. The walls of the hill are nearly vertical, for a distance of 200 to 300 feet down from the top, while the base is surrounded by talus slopes of large quartz bowlders.

The true nature of the formation is not easily determined without a study of the surrounding country. The rock all around it is the aplitic Sterling granite-gneiss, which strikes nearly east and west, while the trend of the quartz range varies from N. 15° E. on Long Hill to due north on Lantern Hill. The whole range of hills is composed of milky quartz, with its surface usually roughened by frost action, and preserving evidence of close jointing in a direction varying from due north to N. 20° E. To all appearance Lantern Hill is an enormous simple quartz vein; but the hill north of the main mass, and also Long Hill, present evidences of a more complicated structure. In these places the quartz is distinctly foliated, often with sericitic or slightly chloritic mica along the planes of schistosity. The rock as a whole is porous and often mottled with rusty spots, and lacks cohesive strength, save for the numerous veins of pure white quartz, which traverse the porous material and form an intricate network. The larger white veins, usually extending in a north and south direction, are connected by numerous smaller veinlets, which diminish in size until they are hardly visible. The veins thicken in places, and branch until, when veinlets are sufficiently numerous, practically the whole rock is impregnated with the vein material, forming a mass of white quartz such as appears in the crest of Lantern Hill.

At the summit of Long Hill, where the surface of the ledge has been protected from frost action, the foliation of the porous quartz strikes in the same direction as that of the aplitic granite which surrounds the hill. This fact suggests the probability that the porous rock was originally

aplite, in which the feldspar has been destroyed and more or less completely replaced by other minerals. Where replacement was not complete, kaolin and ferric oxide were left, staining the rock in the places originally occupied by the feldspar. At the surface, the kaolin and iron rust have been removed by rain water, leaving the ridges of original quartz, perhaps reinforced by infiltrated silica, and held together by the series of branching veins whose general trend is transverse to the foliation.

Many of the veins are full of pockets ("vugs"), lined with small, finely developed quartz crystals; and a comb structure is also a common development. The structure of the whole formation is excellently shown at the Silex mine, situated near the southern end of Long Hill. Here the comb structure and pockets occur in distinct veins, which are often very close together, and connected by branches. Between the adjacent veins is powdery quartz, which can be mined with pick and shovel, without the aid of blasting. The wash of rain water often brings the comby veins into relief, showing the true character of the formation. The powdery quartz at the mine is quite free from iron stains, but frequently shows greenish micaceous particles. The veins forming the comb structure evidently follow a series of joints and minor fractures.

The contact between the quartz mass and the aplite is hidden by talus, but fragments occurring near the contact appear to be aplitic granite in which part of the feldspar has been replaced by quartz. More satisfactory evidence as to the nature of these quartz masses is furnished by outcrops on Swantown Hill and also near Glasgo village. On the northern end of Swantown Hill and also on the hill lying west of it occurs a network of veins, occasionally with comb structure developed. The rock between the veins closely resembles the fine-grained Sterling aplite. Another ledge, north of the village of Glasgo and a little south of the Whipple homestead, shows ramifying quartz veins in schistose aplite, the larger veins following the foliation planes. Here all stages may be traced from pure quartz to unaltered

aplite, with intervening stages of porous quartz and highly silicified aplite. The weathered surface where replacement is incomplete is like that seen on the top of Long Hill, the chief difference here being that the planes of schistosity trend northward, parallel to the veins, while at Long Hill they trend nearly eastward, at a high angle to the veins. In the Glasgo locality, and likewise south of Long Hill, large pegmatite masses are associated with the quartz veins. In these cases, however, the comb structure is absent.

The data at hand warrant the conclusion that Lantern Hill was formerly a granitic mass, which has been converted into quartz by an alteration of the minerals in the granite, and by the addition of silica from quartz-bearing solutions entering the rock. The solutions laden with quartz might have entered the granite prior to the time when jointing was produced, and a formation of quartz veins might have been the final stage of the process by which the pegmatite lying south of the hill was intruded. It seems more probable, however, that the heated waters carrying quartz entered the region after joints had been developed, and that the joints afforded access to the ascending solution. This theory is borne out by the fact that the veins are not ruptured, and that they follow the direction of jointing. It is believed that the solutions ascended through the joints and minor fractures of the shattered rock and impregnated the solid fragments, dissolving the bases from the feldspar and depositing silica. Where replacement was complete, the alumina and iron must also have been carried away. The subsequent percolation of ground water would tend to carry mechanically the kaolin through the porous rock, and, where exposed, the kaolin would be quickly carried away, leaving almost pure quartz grains. An analysis of the rock from Lantern Hill showed about 98% of silica. The few scales of micaceous matter present may be an original constituent of the aplite, or a secondary product formed by the action of the heated solution on the original feldspar.*

* For a different explanation of Lantern Hill, see Kemp, in *Trans N. Y. Acad. Sci.*, Aug. 3, 1896.

Willimantic Gneiss [25].— With the city of Willimantic as a center, and extending about four miles in all directions, there is an area of gneiss consisting of alternating dark and light bands. This formation is well exposed in the river at Willimantic, and has been used in building the dams and mills in this region. The boundary of the gneiss has been drawn arbitrarily, and the entire formation might be considered as the more granitic part of a wide area of schistose gneiss. In general the rock is coarse-grained and oftentimes even porphyritic in structure, usually considerably crumpled and folded. In the quarries about Willimantic two varieties appear, called respectively the light and the dark "stock." The dark variety has relatively a small amount of feldspar and quartz, with a large amount of biotite and some hornblende. The light stock is granitic in texture, and contains quartz, feldspar, and biotite in proportions of normal granite. The porphyritic variety seems to have been produced by the injection of quartz and feldspar, much after the manner of the Putnam gneiss; and, indeed, parts of the Willimantic gneiss present the pseudo-conglomerate appearance possessed by the Putnam. Pegmatite veins are found in this formation; also veins of coarse, reddish granite, such as was formerly obtained from the Stone Hill quarry. There is little evidence in the field to indicate the origin of the Willimantic gneiss, but it is considered as the more injected part of the surrounding schists.

Hebron Gneiss [26].— The Hebron gneiss forms an irregular band almost completely enclosing the Willimantic gneiss. It begins as a narrow belt running through Eastford, Ashford, and Mansfield, and increases in width to five miles through Coventry and Andover; it continues south through Hebron, Marlboro, Chatham, and East Haddam; thence eastward through Colchester and Lebanon. Typical exposures are found south of Coventry village, east of Gilead, in the vicinity of the Lyman viaduct, and at Moodus.

Throughout its entire extent the Hebron gneiss shows a great variety of character in both the composition and the

structure of the rock. It varies from granitic gneiss to highly fissile schist, and it is only when the whole area is taken into account that the term gneiss seems appropriate. Where typically developed, as at Moodus and Coventry, the rock is a fine-grained gneiss, with usually a relatively small amount of feldspar. The biotite is often altered to chlorite, and in places has a purplish tinge; it often gives the whole rock a peculiarly silky luster. The rock weathers readily; and a large amount of quartz is present, which, on exposed surfaces, gives it the appearance of sandstone. Quite generally the rock contains small quantities of pyrite, which, on decomposition, exhibits in places a sulphur-yellow color, and is called locally "sulphur rock." Along its western and northern borders the Hebron gneiss grades into the Brimfield schist, and occasionally contains bands of sillimanite schist. Where the formation approaches the Willimantic gneiss, it is apt to be much more gneissoid in character and much more highly feldspathic. Beds of gray gneissoid granite occur as intrusions in the Hebron gneiss, and areas of porphyritic granite are frequently present. Pegmatite veins — large and small — are of common occurrence in the rock, particularly toward the southwest. In Hebron small areas of muscovite-garnet granite are found as intrusions. In this formation, taken as a whole, intrusions of amphibolite are comparatively rare, but they nevertheless occur, as also do seams of light green, fine-grained pyroxene rock. The Hebron gneiss grades into the Willimantic gneiss on one side and into the Scotland and Brimfield schists on the other; thus the boundary lines of the formation are not to be considered as separating rock of completely different character.

Scotland Schist [27].— This formation covers the town of Scotland, and extends southward through Franklin to Bozrah. From this town it extends westward, occupying a large part of Colchester and East Haddam. The Scotland schist is a coarse muscovite schist, squeezed into minute folds as the result of metamorphism. It consists practically of a mass of muscovite, with some biotite, and occasionally garnet and quartz. The quartz usually occurs in seams or

lenses an inch or less in width, and with it are associated small quantities of chalcopyrite. Rarely specimens of Scotland schist are found which contain sillimanite, the characteristic mineral of the Brimfield schist. The Scotland schist does not commonly possess stringers and bosses of granite, though isolated outcrops of a gneissoid granite occur. It is, however, full of pegmatite veins of all sizes, as may be seen in exposed ledges, and, even more plainly, in the abundance of pegmatite bowlders scattered through the southern part of Scotland. The railroad cut east of Pautipaug Hill shows the schist filled with large and small pegmatite veins, usually interbedded, and a gray gneissoid granite underlying it. The western extension of this formation in Colchester and East Haddam exhibits much of a fine-grained biotite gneiss which forms the characteristic rock in the Hebron gneiss, and it seems probable that the Scotland and Hebron grade into each other. It is believed that the Scotland schist is older than the Willimantic gneiss, and probably conformable with the Putnam gneiss to the east.

Canterbury Granite-gneiss [28].— The entire area of the crystalline metamorphic rocks on the east side of the Triassic is injected by granite, either massive, or developed as gneiss. Usually the intrusions are small dikes or lenses. The Canterbury granite-gneiss, however, is a larger area, and extends for a distance of fifteen miles through Pomfret, Brooklyn, Hampton, and Canterbury. Smaller detached areas occur farther south in Sprague, Franklin, and adjoining towns. This formation consists essentially of a muscovite-biotite gneiss varying from a rock of fine and even grain to one of porphyritic texture, with feldspar crystals a quarter of an inch in length. Metamorphism has produced irregular wavy bands of biotite, separated by flattened layers of quartz and feldspar. At the "Wolf Den" in Pomfret the rock is somewhat schistose, and in other places it grades into a true mica schist. In the region of Westminster it has been quarried, and seems to be quite suitable for flagging and rough stonework.

Middletown Gneiss* [29].—Between the Bolton schist and the Haddam gneiss is an irregular band of rock which should be separated petrographically from the area of Haddam granite-gneiss which it almost surrounds. This is the Middletown gneiss, called by Percival the "anthophyllitic formation," and represented by him as completely encircling the Haddam area. The formation is not marked by any one petrographic type, but by a variety of different rocks. One general characteristic is the presence of hornblende in small grains, or more usually in long prisms or stellar aggregates of prisms. A granulitic structure is another feature which many of the rocks possess, and the outcrops quite generally present an unusually rusty color on the weathered surface. There is, however, a variety of types even in the same outcrop.

The dominant type of rock is a hornblende gneiss thoroughly injected with amphibolite and granitic seams and lenses. The rock where least injected is a fine-grained, light gray to greenish, thin-bedded gneiss which has the following mineralogical composition: — a granulitic base of orthoclase, plagioclase, and quartz, in which lie blades and irregular prisms of hornblende. There is some biotite, and a little titanite, garnet, magnetite, chlorite, and apatite. Tremolite occurs in some slides. The black, thin-bedded variety of gneiss, with well developed schistosity, is a typical amphibolite, and is believed to be intrusive. The origin and age of the Middletown gneiss, and its relation to the other formations, have not been determined, but it seems probable that this heterogeneous group of rock types represents the contact zone between the Haddam granite-gneiss and the surrounding formations. So abundant are the pegmatite intrusions in this area that the top of Bear Hill shows almost no other rock exposed.

Maromas Granite-gneiss† [30].— The Maromas granite-gneiss occupies both sides of the Connecticut River, forming

* See note on page 115.

† See Westgate, *A Granite-gneiss in Central Connecticut*, in *Journal of Geology*, vol. VII, p. 638.

an oval area, with a narrow arm extending northward. The rock exposed in the Maromas quarries is a biotite gneiss of medium to fine grain, varying in color with the amount of biotite present. It is massive in some places, but usually well foliated, and the presence of joint planes parallel with the foliation gives the rock a bedded appearance. The composition of the gneiss as revealed by the microscope is orthoclase, an acid plagioclase, quartz, biotite, microcline, with accessory titanite, magnetite, apatite, and rarely hornblende. There is evidence of a slight amount of crushing. Frequently, as along the northeastern border of this area, this formation becomes a decided "augen-gneiss," with sub-porphyritic aggregates of white and pink feldspar averaging three-quarters of an inch in length. The *augen* sometimes show pink cores with white rims. It seems probable that these cores are parts of the original crystallization of the rock, and that the gneissoid structure was in part produced before the rock was completely solidified. With the exception of the presence of *augen,* this variety does not differ mineralogically from the type shown in the Maromas quarries. Lenticular and linear patches of dark colored rock (*schlieren*) are common in the gneiss, and are composed of the same minerals and have the same structure as the lighter gneiss, except that hornblende replaces quartz. A granulitic facies is developed for a mile along the western border and for a somewhat greater distance about its southern end. This is a fine-grained, light gray or brownish rock of sugary texture, composed of orthoclase, plagioclase, microcline, quartz, and usually garnet. The granulite does not have the character of a crushed granite, but seems to be an endomorphic modification of the granite gneiss in contact with the surrounding rocks. Granulite occurs also with pegmatite veins and as dikes in the granite gneiss.

The Maromas granite-gneiss is eruptive and intruded into the Bolton schist, as is shown by the following facts: — the gneiss often cuts across the foliation of the schist and sends tongues into it, and the contact is frequently irregular; fragments and sheets of the surrounding schist, often with

the minute crumplings intact, occur as inclusions in the gneiss.

Extending from a mile below Middle Haddam to South Glastonbury is a belt of rock about a quarter of a mile wide, which is quite different in field appearance from the typical Maromas gneiss. Very dark biotite gneisses and amphibolites are characteristic of this area. Some of these more basic rocks seem to be part of the original molten mass, but many of the amphibolites are later intrusions. So abundant are these hornblendic eruptives that no attempt is made to distinguish them on the map. Pegmatite veins, mostly from a few inches to ten feet in width, occur abundantly in the gneiss.

Haddam Granite-gneiss [31].— This granite-gneiss occupies an area, triangular in form, with its base near the Sound and its apex on the Connecticut River north of Higganum, and forms a large part of the country between the Sound, the river, and the eastern border of the Triassic sandstone.

The typical rock of the area is well exposed about Higganum on both sides of the Connecticut. It is a light colored, rather fine-grained granitic aggregate of quartz and feldspar, through which are scattered small isolated flakes of biotite, which give an indistinct foliation to the rock. Hornblende is sometimes present in addition to the biotite. Plagioclase is present, but is less abundant than the orthoclase. Small garnets are common. In most of the outcrops the rock is a moderately thick-bedded gneiss, and usually crumbles readily on weathered surfaces.

About a half-mile inside the northern boundary of the area, and with a direction roughly parallel to its border, is a belt of hornblende gneiss and amphibolite, which separates the granite-gneiss described above from a belt of darker, thinner-bedded gneisses, which are at a number of places quarried for flagstones, and which comprise the outer zone of the Haddam gneiss. This belt of hornblende gneisses cannot be traced for more than a mile from the river either to

the west or east, and the difference in the granitic gneisses north and south of it is probably merely a local variation, without stratigraphic importance. This flagstone facies of the Haddam is well shown in the small quarries near the river two miles north of Higganum. The rock is a dark gray, quite micaceous, well foliated gneiss. Hornblende is usually present, but in less amount than the biotite, though in one or two localities it is the more abundant of the two minerals. Orthoclase is more abundant than plagioclase. Quartz is present, and magnetite, apatite, and garnet occur in small quantities as accessories.

At Walkley Hill a hornblendic rock occurs in the Haddam granite-gneiss, in the same relative position as the band farther north, and is possibly the continuation of that band. West of the river, to the north, this amphibolite can be traced for nearly a mile. The strike of the foliation or banding in the northern part of the Haddam gneiss is parallel with the border of the formation. The dip is everywhere toward the border. From its composition and field relations it is inferred that the Haddam gneiss is probably of igneous origin.

Branford Granite-gneiss [32].— This gneiss occupies a narrow area along the shore of the Sound, extending from Lighthouse Point on the east side of New Haven harbor, to Haycock Point some twelve miles farther east. On the north it is bounded by the Triassic sandstone and Middletown gneiss, while the Stony Creek granite-gneiss forms the eastern boundary. Its area is about twelve square miles. The best exposures are in the railroad cut, a half-mile west of Pine Orchard station. The rock is a medium-grained granite, with a banded structure, consisting very largely of white feldspar. In the feldspars are imbedded small round quartz grains, having a slightly brownish tint, and biotite is present in about equal amount. Small reddish garnets are commonly found in the rock, though at times they may entirely fail. The rock throughout has a pronounced tendency to weather with a brownish stain on the cleavage surfaces of the feldspar. It is strongly injected with pegmatite; and

in places evident traces of a gneiss infolded in the granite and pegmatite are to be seen, as along the shore between Pine Orchard and Indian Neck. The gneissic structure of the rock is not uniform; at some localities, as at Lighthouse Point, it is quite indistinct, and the rock has much the appearance of a true granite. Jointing in the rock is pronounced at all points, especially in the western portion.

Stony Creek Granite-gneiss * [33].— The principal area covered by this rock is roughly semicircular in outline, extending a distance of six miles along the shore from Haycock Point to West River in Guilford. Its most northern point is about three and one-half miles inland. A much smaller area is found in the vicinity of Clinton. The rock presents some diversity of type, but in general may be described as follows:— a rock of grain medium to coarse, composed very largely of flesh-colored to pink orthoclase crystals, with white albite, small gray quartz grains, muscovite, and biotite in subordinate amounts. Under the microscope, in addition to the above minerals, small magnetite, apatite, and zircon crystals are seen to be present. The red tone of the rock is due to the predominance of the orthoclase over all other minerals. Variations in appearance are due to differences in the size of the crystals composing the rock, which, although generally medium-grained, is sometimes much coarser, and more rarely considerably finer, than the common type. Differences in the amounts of the red and white feldspars, and different degrees of segregation of the biotite, also cause noticeable variations in appearance.

In larger masses the rock commonly displays a banded structure, due to the fact that the different minerals are separated more or less completely from one another in narrow layers, ranging from a minute fraction to a half-inch in thickness. At many points, also, the pink orthoclase layers show lens-shaped enlargements, which are proved by the microscope to be larger crystals (phenocrysts) or groups of

*The granite-gneiss and related formations of the Stony Creek district were studied by Dr. W. E. Ford, while associated with Professor Gregory in work for the U. S. Geological Survey. The description here is based largely on his work.

crystals somewhat crushed and drawn out. It is certain that the rock at some localities, especially at Hoadley Point, has been greatly squeezed. This is obvious to the eye, and further evidence is obtained from thin rock sections when studied with the microscope. There is considerable fine-grained red, rarely gray, granite and pegmatite associated with the Stony Creek granite-gneiss, cutting it as veins. The pegmatite is also developed as small coarse-grained areas in the normal rock. The composition of these later veins is the same as that of the country rock, with the addition of occasional pyrite crystals. Pegmatite veins are most common near the border of the area, the great majority of them lying within a marginal zone a half-mile wide. There are also associated with this formation small included masses of a biotite-hornblende gneiss. The relations of the two rocks are well shown in the railroad cuts. There the gneiss above mentioned, cut by veins of the Stony Creek granite-gneiss, and even entirely surrounded by it, furnishes clear proof that the granite-gneiss is intrusive and younger than the biotite-hornblende gneiss.

The granite-gneiss is decidedly broken by faults and joint planes. Certain of these joints (most obviously a series of horizontal ones) are probably due to the partial relaxing of stresses originally present in the mass when deeply buried; others are due to later crustal movements which extended over the entire state. In general the rock is too broken to be of great value for quarrying, although there are a number of localities where it is sufficiently massive to make good building material.

Lyme Granite-gneiss * [34].— The area occupied by this formation is of irregular shape, covering portions of the towns of Lyme, Old Lyme, and East Lyme. The boundary between it and the Mamacoke gneiss is fairly well marked in Old Lyme and East Lyme. The boundary on the north is less satisfactory, on account of the confused manner in

* The geology of southern Connecticut from Saybrook to Mystic was studied by Dr. H. H. Robinson during the summer of 1904. The descriptions of the Lyme and New London granite-gneisses and of the Mamacoke gneiss were written by him.

which this rock has broken through the Mamacoke gneiss, and also on account of the extensive covering of Glacial till. The best exposures are found along the Connecticut River north of Lyme, on the north and west sides of Rogers Lake, and at the quarry on Rocky Point near South Lyme. At those localities the rock is massive and of medium grain; the color is generally light red, shading to gray. It is composed essentially of pink orthoclase, quartz, and albite, with a small, though somewhat variable, amount of biotite, and occasional crystals of hornblende. The gneissic structure of the rock is well developed throughout the area, especially in the more northern portions. There is considerable pegmatite associated with the granite-gneiss, in the form of coarse-grained veins and spots in rock of normal grain. Outcrops of the pegmatite appear more numerous in the southern parts of the area and especially near the boundary. Its composition is quite the same as that of the country rock. In texture it is granitic with only occasional suggestions of banding. The pegmatite, as well as the granite-gneiss, is well exposed in the Luce quarry on Rocky Neck.

New London Granite-gneiss [35].— The rock included within this area, which has been marked off from the Mamacoke gneiss by a rather arbitrary boundary, is distinctly granitic in character. Typical exposures in and about New London exhibit a light gray, rather fine-grained rock of uniform texture, composed largely of feldspar and quartz with subordinate brilliant black biotite and occasional hornblende crystals. At some exposures a few small garnets may be found. On account of the small amount of biotite, the gneissic structure is less pronounced than in the rocks containing more of that mineral. Outcrops about one mile west of New London on the road to Jordan Village are streaked with veins and nodules of pinkish feldspar, which is sometimes intergrown with quartz in the manner of graphic granite. Seams and patches of a dark colored biotite gneiss are here seen, included in and cut by the granite-gneiss. The rock of this formation is generally firm in texture, and is quite largely used locally for the foundations of buildings.

Mamacoke Gneiss [36].— From Guilford to the Connecticut River this gneiss occupies an elongated area, one to four miles in width, bounded on the north by the Middletown gneiss and on the south by the Stony Creek granite-gneiss, and by the Sound. From Essex it extends northward to Chester. It then turns eastward; and, gradually spreading out, occupies the greater parts of the towns of Salem, Montville, Waterford, and Groton, with lesser portions of Lyme, East Lyme, East Haddam, Ledyard, Stonington, and North Stonington. A small detached area is found in the southeastern part of Old Lyme. The rocks occupying the larger area are in some localities decidedly gneissic, containing much biotite and more rarely hornblende, but elsewhere they are very granitic in appearance. These different types of rock are probably of different age, and possibly of different origin; but much work in the field will be necessary to separate the several varieties and determine the many questions that they suggest.

In that portion of the area west of the Connecticut River the predominant rock is uniformly medium-grained, light to dark gray in color, and consists of white feldspar and quartz, with brilliant black mica, and sometimes small amounts of hornblende or garnet. In typical specimens the dark minerals constitute about one-third of the mass; but the range in both directions is considerable, giving rise in one case to a biotite gneiss, in the other to a granitic gneiss. Throughout the area the banding of the rock is plainly evident on account of the contrast in color between the layers of white feldspar and quartz and those of black biotite. The rock for the most part appears fresh and firm in texture. It has been used locally for building purposes; and, where the structure permits, it has been quarried for flagging. This gneiss is typically developed in the vicinity of Horse Hill, northeast of Clinton. Farther east, along the Connecticut River from Saybrook Junction to Essex, the rock is finer-grained and appears to be considerably more altered. There is a noticeable injection of granite into this, as well as into the more typical rock, along a zone beginning at the first outcrops

west of the river opposite Lyme, and extending in a south-westerly and westerly direction for over two miles.

In the region extending from Essex through Deep River and eastward to the vicinity of Salem, the gneiss as a whole is rather more granitic and contains areas of a later granite. Exposures of the typical Mamacoke gneiss occur in and southeast of Deep River and in the northwest corner of the formation in Chester. Elsewhere the rock has a lighter color, due to the presence of a smaller amount of biotite, which also results in a less prominent banding. The tone of the rock is generally brownish — the feldspar being stained by the iron set free by the decomposition of the biotite, — sometimes reddish when pink feldspar is present. The grain of the rock is fine to medium, never coarse. The rock on Selden Neck, opposite Deep River, is quite different from that surrounding it, and is a later intrusion of granite. It is composed largely of pink orthoclase, with small amounts of clear quartz and black biotite. Banded structure is prominent, and the biotite is arranged in more or less parallel lamellæ and lenses rarely over three inches in length.

The larger portion of this area, lying to the east and west of the Thames, consists of an apparently complicated mixture of older gneisses injected and broken by later intrusions. They are for the most part granitic in character; and because of this fact and the pronounced alterations they have undergone at many localities, the work of separating them is of considerable difficulty. The work of one field season was only sufficient to make the above point evident and furnish a basis for future study. We may say, as Percival said in his report, "The first five ranges (east of the Connecticut River) may be regarded as continued in that part of the formation, extending through Montville, Groton, and Ledyard; but I have not been able to trace them there with sufficient distinctness to enable me to discriminate them as in that part of the present section already described."

The exposures in the abandoned quarry about a half-mile south of the United States Naval station, and on

Mamacoke Island opposite the station, are typical of a very large part of the area. At the quarry the exposure may be divided into two parts — the eastern consisting of many alternating bands, usually less than two feet thick, of black biotite and white feldspar and quartz; the western, a normal reddish gray granitic gneiss. Both are strongly folded, as may be seen by inspecting the banded portion of the exposure. In the upper part of the quarry is a dike, two or three feet thick, of fine-grained, gray to faint reddish granite. It is younger than the gneiss, and cuts across it in an east and west direction, descending at an angle of about 25° toward the south. A rock similar to that of the dike is found in small scattered outcrops throughout this region, and is of the same character as that quarried at Westerly, Rhode Island, and at Millstone Point and the Booth quarry in the town of Waterford.

The detached area in Old Lyme shows notable injection by the Lyme granite-gneiss and pegmatite near Black Hall. One small but interesting exposure on the line of the railroad and just east of Mill Creek may be noted. It shows the Mamacoke gneiss cut by coarse red pegmatite, and both the gneiss and pegmatite cut by a small dike of fine-grained biotite granite. Since the pegmatite is always found associated with the granite-gneiss, a certain order of events, confirmed at other localities, may be made out. The Westerly, Waterford, Millstone, and other gray to red, fine-grained granites are intrusive, generally as dikes, in the Stony Creek, Lyme, New London, and Sterling granite-gneisses and in the Mamacoke gneiss; and these granite-gneisses are intrusive, generally as bosses, in the Mamacoke gneiss. What position in geological time to give these three groups of rocks is not evident. One can only say that the differences between the gneiss and granite-gneisses are quite sharply defined, and must represent a considerable interval of time. The pegmatite is, as we have seen, contemporaneous with the granite-gneisses, while the fine-grained granite (Westerly, etc.) may be considered as the final product of the granite-gneiss period of intrusion or as distinctly later than that period.

Preston Gabbro-diorite* [37].— A region of dark colored rock forms a roughly oval area in parts of Preston, Griswold, North Stonington, and Ledyard. In character the rock shows a number of variations, and follows a definite gradation from the center of the mass toward the periphery. The central part in the vicinity of Bay and Rixtown Mountains is a coarse porphyritic gabbro containing phenocrysts often over two inches in length. These larger crystals are set in a ground-mass of labradorite and green hornblende, occasionally accompanied by pyrite and garnet. The coarse gabbro is cut by veins of pegmatite and small dikes. The pegmatite occurs as short veins and lenses, sometimes without distinct borders. Its chief constituent minerals are hornblende and plagioclase feldspar. Quartz occurs in it, but is never abundant. Narrow, short dikes, probably of diabase, cut both gabbro and pegmatite.

Forming a zone around this central mass of gabbro, and exposed on Bay, Lambert, and Rixtown Mountains, is a medium-grained dark rock having the composition of diorite. The mineral constituents are similar to those of the gabbro, but the feldspar is andesine and the hornblende is distinctly crystallized.

At the margin of the mass the rock becomes a quartz diorite. Metamorphism occurs where the igneous mass came in contact with the schists and gneisses of the region, and the resulting heat has converted slates into hornstone. Fragments of hornstone are also found included in the gabbro, and stringers of the igneous rock are seen to enter the schists. Regional metamorphism has produced schistosity in the rocks surrounding the mass, and has affected the border of the quartz diorite zone. The gabbro and diorite masses have been profoundly altered, but they lack the gneissoid structure. The strike of the foliation planes of the surrounding rock follows the borders of the igneous mass, and it appears that the main mass of gabbro-diorite effectively resisted the pressure which resulted in the production of schistosity in the other types of rock.

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* See note on page 132.

The data at hand lead to the conclusion that the Preston gabbro-diorite is a bathylith — a deep-seated igneous mass exposed to view by removal of the overlying rocks. When the heated rock invaded the ancient sediments, they were baked and recrystallized as a result of the severe heat. Later, schistosity was developed in this region, but the bathylith was too firm to yield to the pressure which so completely modified the surrounding rocks.

Westerly Granite.— Along the eastern Connecticut shore line and extending into Rhode Island are found a number of exposures of gray and pink granite, which are apparently of the same character and age. This rock is quarried at several places, but particularly at Westerly and Niantic, Rhode Island, just east of the Connecticut line, whence the formation receives its name. Smaller quarries have been opened west of Pawcatuck River in Stonington. Of late years these localities have furnished large quantities of rock for building and especially monumental work.

At Westerly two varieties of rock are quarried:— a finely crystalline, gray rock, which shows minor variations in color and texture, but which is petrographically the same, and which is the Westerly granite of commerce; and a light red coarse granite (the Sterling granite-gneiss), which somewhat resembles the rock from Stony Creek, but is much finer. The small quarries in Mystic and Groton furnish a gray variety, although the rock from the latter place is somewhat coarser than the typical Westerly. The Waterford and Millstone Point quarries yield stone which is almost identical with the Westerly.

Where typically exposed the Westerly granite is massive, with no indication of gneissoid structure; it is, however, cross-jointed and broken into blocks. Quartz, biotite, and a small amount of muscovite are the chief minerals composing the rock, hornblende being entirely absent.* In the Westerly quarries small spots of a black, pitchy material,

* For a petrographic description of the Westerly granite, the reader is referred to a paper by Professor J. F. Kemp, in *Bull. Geological Society of America*, vol. X, pp. 361-382.

probably allanite, occasionally occur, giving the rock the local name of "bedbug granite." The variation in color from red to bluish gray seems to be caused by the variation in degree of oxidation. That oxidation takes place readily is apparent from the fact that fragments discarded from the quarry are pinkish at the surface, while the interior is still gray.

The Westerly granite is of an intrusive nature, and has been thrust into the Sterling granite-gneiss and other formations along the shore line. This rock is seen to send out irregular stringers into the surrounding gneisses, and to contain inclusions of amphibolite and other rocks. The relation between the different rocks of this area seems to be as follows: — the Sterling granite-gneiss is injected into earlier sediments; pegmatites cut the Sterling granite-gneiss; and the Westerly granite is intrusive in pegmatites and granite-gneiss alike, and thus is the youngest formation in the south-eastern part of Connecticut.

The areas of Westerly granite are too small to be shown on a map of the scale of Plate XIV.

Pegmatite.— Pegmatite is widely distributed over the eastern crystallines, and presents no peculiarities which distinguish it from similar rocks in the western part of the state (see page 110). Putnam gneiss, Sterling granite-gneiss, and Scotland schist are especially full of pegmatite veins, but their distribution is scarcely less abundant in the other formations. Certain areas, like the White Rocks south of Middletown and the hill near Leesville, as well as a district south of Lantern Hill, contain unusually large and unusually abundant pegmatite masses. For a description of the nature of pegmatite the reader is referred to page 71.

Amphibolite [38].— As indicated in the descriptions of the various formations, amphibolite is abundant in the eastern part of Connecticut. Its composition and mode of occurrence are identical with those of the amphibolite of the western crystallines (see page 112).

Diabase Dikes [39].— Intrusions of diabase in the form of dikes are an even more common feature in the crystallines of the eastern portion of the state than in those of the western.* The dikes are not distributed in haphazard fashion, but form two belts, one extending from Manchester to West Stafford, and the other constituting a remarkable series extending from Branford northeastward to Union, a distance of probably seventy miles. In some places the dikes are prominent topographic features, but usually they present no conspicuous surface forms, and it is a testimony to Percival's great skill as a field observer that he was able to trace the dikes and connect the inconspicuous scattered outcrops. In general the texture and composition of the dikes on the eastern side of the Triassic area are identical with those along the Housatonic, but there is apparently a greater amount of crushing and more alteration of the constituent materials. These dikes are believed to be of the same age as the Triassic sedimentary strata with their accompanying traps.

* For a description of the Triassic intrusions of the western crystallines see page 113.

Chapter III

The Triassic

By
WILLIAM NORTH RICE

Mamacoke Gneiss [36].— From Guilford to the Connecticut River this gneiss occupies an elongated area, one to four miles in width, bounded on the north by the Middletown gneiss and on the south by the Stony Creek granite-gneiss, and by the Sound. From Essex it extends northward to Chester. It then turns eastward; and, gradually spreading out, occupies the greater parts of the towns of Salem, Montville, Waterford, and Groton, with lesser portions of Lyme, East Lyme, East Haddam, Ledyard, Stonington, and North Stonington. A small detached area is found in the southeastern part of Old Lyme. The rocks occupying the larger area are in some localities decidedly gneissic, containing much biotite and more rarely hornblende, but elsewhere they are very granitic in appearance. These different types of rock are probably of different age, and possibly of different origin; but much work in the field will be necessary to separate the several varieties and determine the many questions that they suggest.

In that portion of the area west of the Connecticut River the predominant rock is uniformly medium-grained, light to dark gray in color, and consists of white feldspar and quartz, with brilliant black mica, and sometimes small amounts of hornblende or garnet. In typical specimens the dark minerals constitute about one-third of the mass; but the range in both directions is considerable, giving rise in one case to a biotite gneiss, in the other to a granitic gneiss. Throughout the area the banding of the rock is plainly evident on account of the contrast in color between the layers of white feldspar and quartz and those of black biotite. The rock for the most part appears fresh and firm in texture. It has been used locally for building purposes; and, where the structure permits, it has been quarried for flagging. This gneiss is typically developed in the vicinity of Horse Hill, northeast of Clinton. Farther east, along the Connecticut River from Saybrook Junction to Essex, the rock is finer-grained and appears to be considerably more altered. There is a noticeable injection of granite into this, as well as into the more typical rock, along a zone beginning at the first outcrops

west of the river opposite Lyme, and extending in a southwesterly and westerly direction for over two miles.

In the region extending from Essex through Deep River and eastward to the vicinity of Salem, the gneiss as a whole is rather more granitic and contains areas of a later granite. Exposures of the typical Mamacoke gneiss occur in and southeast of Deep River and in the northwest corner of the formation in Chester. Elsewhere the rock has a lighter color, due to the presence of a smaller amount of biotite, which also results in a less prominent banding. The tone of the rock is generally brownish — the feldspar being stained by the iron set free by the decomposition of the biotite, — sometimes reddish when pink feldspar is present. The grain of the rock is fine to medium, never coarse. The rock on Selden Neck, opposite Deep River, is quite different from that surrounding it, and is a later intrusion of granite. It is composed largely of pink orthoclase, with small amounts of clear quartz and black biotite. Banded structure is prominent, and the biotite is arranged in more or less parallel lamellæ and lenses rarely over three inches in length.

The larger portion of this area, lying to the east and west of the Thames, consists of an apparently complicated mixture of older gneisses injected and broken by later intrusions. They are for the most part granitic in character; and because of this fact and the pronounced alterations they have undergone at many localities, the work of separating them is of considerable difficulty. The work of one field season was only sufficient to make the above point evident and furnish a basis for future study. We may say, as Percival said in his report, "The first five ranges (east of the Connecticut River) may be regarded as continued in that part of the formation, extending through Montville, Groton, and Ledyard; but I have not been able to trace them there with sufficient distinctness to enable me to discriminate them as in that part of the present section already described."

The exposures in the abandoned quarry about a half-mile south of the United States Naval station, and on

THE TRIASSIC.

HISTORICAL REVIEW.

In these brief historical notes it is not proposed to mention all the geologists who have done valuable work in the study of the formation in question. Still less is it proposed to give a complete bibliography of the subject. There is less need of this, in view of the fact that a very full and accurate index to the literature of the subject prior to 1892 is given in Professor I. C. Russell's "Correlation Paper" on the Newark System, published as Bulletin No. 85, of the United States Geological Survey. While some important observations were made at an earlier date by the elder Silliman and others, the systematic study of the Connecticut Trias commenced with the appointment of J. G. Percival as State Geologist, in 1835. His report was published in 1842. That report was an admirable piece of work, as regards the conscientious thoroughness with which the local distribution of the various kinds of rocks was described. The science of dynamical geology was then too little developed to afford a basis for any satisfactory interpretation of the facts, and Percival seems to have chosen almost entirely to refrain from any intimation of theoretical interpretations, if he had any such in mind. Professor J. D. Dana, who held so long an honored place at the head of American geologists, devoted considerable time to the study of the Triassic formation as exhibited in the immediate vicinity of New Haven. His latest views may be found in his little book "On the Four Rocks of the New Haven Region," published in 1891, and in his "Manual of Geology," of which the latest edition was published in 1895. Professor Dana was led into error in regard to the relations and history of the trap rocks of the area by the assumption that inferences drawn from the trap-hills in the immediate vicinity of New Haven could be ex-

tended without qualification to other parts of the area. He was undoubtedly right in the judgment that the trap of East and West Rock is intrusive, but he failed to appreciate the evidence adduced by Davis and others proving the very different relations of the line of trap ridges in the middle of the Connecticut Valley area. To Professor W. M. Davis, more than to any other man, is due the correct interpretation of the relations of the sandstones and the associated trap rocks of Connecticut. His studies in the region commenced in 1882, and were continued for several years, the latter part of the time under the auspices of the United States Geological Survey. A number of geologists served as assistants in this investigation, among whom were C. L. Whittle, E. O. Hovey, H. B. Kümmel, W. N. Rice, S. W. Loper, and L. S. Griswold. The latest of Professor Davis' Papers, giving in most complete form the results of the whole investigation, was published in 1897, in the Eighteenth Annual Report of the United States Geological Survey. That paper is by far the most important work for the student of this formation in Connecticut. In 1901 Professor W. H. Hobbs published a valuable paper on "The Newark System of Pomperaug Valley," in the Twenty-first Annual Report of the United States Geological Survey. This paper gives the fullest account of the curious little area of the Triassic formation in the towns of Woodbury and Southbury.

The Connecticut student will of course be interested in the investigations which have been carried on in the more northerly portion of the Connecticut Valley area, lying in the State of Massachusetts. Substantially contemporaneous with the investigations of Percival in Connecticut were those of Edward Hitchcock in Massachusetts. His "Final Report on the Geology of Massachusetts" was published in 1841. In later times the study of the Triassic of Massachusetts has been carried on with great zeal and ability by Professor B. K. Emerson. His "Geology of Old Hampshire County" was published in 1898, as Volume XXIX of the Monographs of the United States Geological Survey. Parts of the Connecti-

cut Valley area are mapped in detail, with explanatory text, in the Holyoke Folio of the Geologic Atlas of the United States, by B. K. Emerson, and in the Farmington Folio by H. E. Gregory.

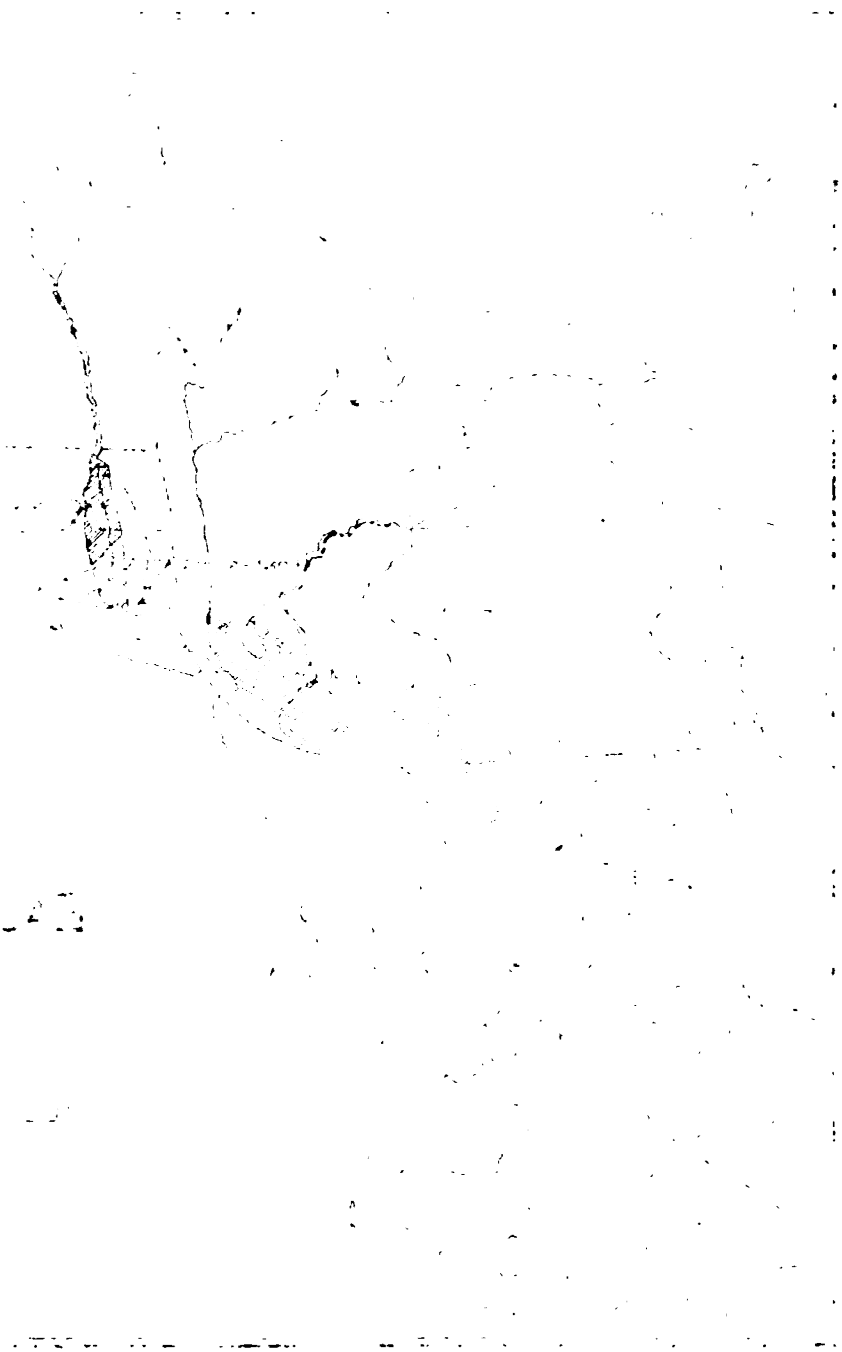
Much light has been thrown upon the Triassic formation of Connecticut by the study of the contemporaneous formations in other parts of the country. Much valuable work has been done by the Geological Survey of New Jersey. Two papers may be commended to the student as of special value in regard to the Triassic formation in New Jersey; namely, Kümmel's "The Newark System of New Jersey," in the Annual Report of the State Geologist of New Jersey for 1897, and Darton's "The Relations of the Traps of the Newark System in the New Jersey Region," published as Bulletin No. 67 of the United States Geological Survey. On the more southerly areas of the Triassic formation, the most important paper is Shaler and Woodworth's "Geology of the Richmond Basin," published in the Nineteenth Annual Report of the United States Geological Survey. Professor Russell's paper already referred to gives an admirable summary of the results of the study of all the Triassic areas of eastern North America down to 1892.

A few works may well be mentioned bearing especially upon the fossils of the formation. Hitchcock's "Ichnology of Massachusetts" gives the results of the author's patient and earnest study of the tracks of animals on the sandstones, of which he had accumulated a magnificent collection in the museum of Amherst College. For a later revision of the study of these tracks, in the light of present knowledge of paleontology and comparative anatomy, the student may be referred to a memoir by Professor R. S. Lull on the "Fossil Footprints of the Jura-Trias of North America," in the fifth volume of the Memoirs of the Boston Society of Natural History. The fossil fishes are described in Newberry's "Fossil Fishes and the Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley," published as Volume XIV of the Monographs of the United States Geological Survey. A more recent review of the fossil fishes, by

Dr. C. R. Eastman, is found in the Annual Report of the State Geologist of New Jersey for 1904. For the plants of the formation reference may be made to the above cited work of Newberry, and also to Fontaine's "Contributions to the Knowledge of the Older Mesozoic Flora of Virginia," published as Volume VI of the Monographs of the United States Geological Survey.

THE STRATIFIED ROCKS.

Areal Distribution.— The Triassic formation in eastern North America is represented by deposits of essentially similar type distributed in isolated areas from Nova Scotia to North Carolina. The principal areas are the following (see Plate XV):— 1, Acadian area; 2, Connecticut Valley area; 3, Pomperaug Valley area; 4, New York-Virginia area; 5, Barboursville area; 6, Scottsville area; 7, Taylorsville area; 8, Farmville area; 9, Richmond area; 10, Danville area; 11, Dan River area; 12, Deep River area; 13, Wadesboro area. Besides these there are a number of small patches of the formation in question, which are obviously outliers of the larger areas separated from them by erosion. The Acadian area lies chiefly in Nova Scotia along the southeastern shore of the Bay of Fundy. It includes, however, some small isolated patches in the adjacent part of New Brunswick. The Connecticut Valley area extends from near the northern boundary of Massachusetts to New Haven in Connecticut. The course of the Connecticut River from Turner's Falls, Massachusetts, to Middletown, Connecticut, lies in this Triassic area; but from Middletown to Saybrook the Connecticut River flows in a gorge which it has carved through the older crystalline rocks. The Pomperaug Valley area is a small area drained by the Pomperaug River, lying in the towns of Woodbury and Southbury, Connecticut. This area and the southern part of the Connecticut Valley area are shown in the map, Fig. 1, page 19. The New York-Virginia area is the most extensive continuous area of Triassic rocks in eastern North America. Beginning on the west bank of the Hudson at the Palisades, it extends in a



general southwesterly direction, but in a sinuous curve convex to the southeast at both ends, but convex to the northwest in the middle, across New Jersey, Pennsylvania, and Maryland, into Virginia. The Barboursville, Scottsville, Taylorsville, Richmond, and Danville areas are all situated within the state of Virginia. Of these the most extensive are the Richmond and the Danville area. The Dan River area lies chiefly in North Carolina, and the Deep River and the Wadesboro area are entirely within that state. Wells bored through the later strata have revealed the presence of the Triassic rocks beneath the surface in South Carolina, but nothing definite is known of their extent.

Kinds of Rocks.— The rocks in all these areas would naturally be characterized in a broad way as red sandstones. The sandstones, sometimes coarse, sometimes fine, consist mainly of grains of quartz, feldspar, and mica, resulting from the disintegration of the older rocks which form the walls of the troughs in which the sandstones were deposited. The prevailing red-brown colors of the sandstones are due not to the constituent grains, but to the cementing material, which contains a large amount of ferric oxide.* These sandstones have been much used as building stones. In large and massive buildings they have an imposing effect, though the dark color is thought by some to make their aspect rather somber. When care is taken to place the blocks in a wall with the lamination horizontal, the stone proves very durable. When the rocks are laid with the lamination vertical and parallel to the face of the wall, the action of frost often results in the peeling off of the outer layers.

These sandstones have been extensively quarried in Portland, Fair Haven, and Manchester; and small quarries, chiefly for local supply, have been opened in numerous other places.

The following analysis of the sandstone from Portland is taken from Professor Gregory's paper in the Farmington Folio of the United States Geologic Atlas:—

* For discussion of the origin of this ferruginous material, see Russell, *Subaerial Decay of Rocks* (*Bull. U. S. Geological Survey*, No. 52), p. 44.

SiO_2	70.11
Al_2O_3	13.49
FeO and Fe_2O_3	4.85
MnO	.35
CaO	2.39
MgO	1.44
Na_2O,K_2O,H_2O	7.37
	100.00

While the name sandstone would properly express the prevalent and typical character of the rocks of the formation, the material is in some strata so coarse as to deserve the name of conglomerate, and in others so fine as to deserve the name of shale. In the conglomerates, the pebbles may be less than an inch in diameter, but they are sometimes much coarser. In some localities occurs a rock which has been called "giant conglomerate," in which some of the bowlders are several feet in diameter. The conglomerates occur chiefly near the borders of the Triassic areas, and in these it is especially easy to recognize the rocks from the disintegration of which the pebbles have been derived. In general, it may be said that the pebbles in any particular area are derived from rocks in the immediate vicinity. The conglomerates in the Connecticut Valley area are obviously derived from the gneisses, schists, and pegmatites, which are the prevalent rocks of the Eastern and Western Highlands. In some cases, however, it has been observed that the pebbles of the conglomerates are derived from rocks which are found *in situ* not immediately adjacent to the locality of the pebbles, but at a distance of a number of miles. This may indicate that the waters in which the conglomerates were deposited were traversed by currents, tidal or otherwise, of considerable force.* In some cases, however, the dissimilarity between the pebbles in the marginal conglomerates and the rocks *in situ* in the immediate vicinity is doubtless due to the presence of faults.† The frequent oc-

* Emerson, *Geology of Old Hampshire County*, pp. 355, 374.

† Kümmel, *The Newark System of New Jersey*, in *Ann. Rep. State Geologist*, 1897, p. 56.

currence of faults at the border of the formation will be discussed later.* The beautiful calcareous breccia called Potomac marble is a conglomerate occurring in parts of the New York-Virginia Triassic area derived from the disintegration of limestones which formed a part of the wall of the trough.

The shales, like the sandstones and conglomerates, are prevailingly red, owing their color likewise to the presence of ferric oxide. Some strata of shale, however, contain in considerable quantity hydrocarbon compounds derived from the decomposition of organic matter. These bituminous shales are accordingly nearly black. In the Connecticut Valley area, there are two thin strata of these bituminous shales, which have been shown, by careful search for outcrops, to have a very wide extent.† One of these lies between the anterior and the main sheet, and the other between the main and the posterior sheet of contemporaneous trap, which will be subsequently described.‡ A few outcrops of the black shale have been observed, which appear to indicate at least local deposits at a still higher horizon. At several localities fossil plants and fishes are abundant in these shales.§ In connection with these black shales are found thin films of coal. It is, however, safe to say that no coal beds of workable extent will ever be found in the Triassic formations of Connecticut. In the Connecticut Valley area the strata dip somewhat uniformly to the east, and the edges of the whole series of strata are exposed by erosion. The deepest and oldest strata, therefore, crop out near the western border of the formation. Strata of coal of sufficient thickness to be of commercial value would certainly have been discovered in the thorough study which has been given to this formation. To make expensive borings in search of coal is a foolish waste of money. While no workable beds of coal have been found in any of the northern Triassic areas, such beds have been found in the Richmond, Farmville, Dan River, and Deep River areas. Besides the films of coal

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* Page 213.

† Davis and Loper, in *Bull. Geological Society of America*, vol. II, p. 415.

‡ Page 186.

§ For mention of localities, see paper of Davis and Loper above cited.

found in Connecticut with the black shales, fragments of lignite are occasionally found scattered through the sandstones. It is an interesting fact that the sandstones containing these fragments of lignite are not red, but gray or white, the ferric oxide having been reduced by the decomposing vegetable matter.

A small amount of impure limestone is also included in the Triassic formation of Connecticut. A thin stratum has been recognized in several localities lying a little above the anterior sheet of contemporaneous trap.

Conditions of Deposition.—The Triassic formations of eastern North America appear to be estuarine rather than marine in origin. The prevailing red color of the rock indicates other than marine conditions. The exuberance of life in the shallow waters of the seashore usually affords so much decomposing organic matter as to reduce any ferric oxide which may be present. Red sandstones and shales in general indicate estuarine or lacustrine rather than marine conditions. This indication afforded by the rock itself is confirmed by the character of the fossils, of which more will be said later.* Here it may simply be remarked that (with the exception, apparently, of a very few molluscan shells) no marine fossils have been found in any of the Triassic formations of eastern North America, but only remains of fresh-water and terrestrial life.

One of the most obvious conclusions in regard to the rocks is that they were deposited in shallow water. The thick beds of sandstone often show oblique lamination in varying directions. This indicates that the sands were swept along by changing currents. That is exactly the condition which would exist in a tidal estuary. Many of the layers have their surface marked with the alternation of ridge and furrow known as ripple-mark. Whether this structure is due to the oscillation of the water at the bottom in connection with waves at the surface, or to currents in the water heaping up the sand as in miniature dunes, it is certain

* Page 170.

that it can be formed only in comparatively shallow water. Other markings frequently found on the surface of the layers show that the surface was sometimes left bare by receding tides or subsiding freshets before the deposit had consolidated. Such evidence is afforded by the little pits impressed occasionally on the sand or mud by the drops of a short spatter of rain; also by the network of cracks, often rudely hexagonal in their arrangement, formed by the shrinkage of the mud as it dried in the sun. Testimony of the same sort is borne by the tracks of reptiles and other animals that walked over the still soft sands or muds.* A curious coincidence often observed is the radiation of mud-cracks from the tips of the toes of tracks. The obvious meaning is that the drying of the mud had reached the point at which it was just ready to crack, and the disturbance made by the footstep overcame the force of cohesion and so started the crack.

As has been already remarked, the strata of the Connecticut Valley area have a prevalent dip to the east, and the edges of the whole series of strata have been exposed by erosion. It will be seen hereafter that the tilting of the strata was accompanied by a good deal of fracturing and faulting. In a generalized and diagrammatic fashion the present condition of the strata is represented in Fig. 2.

A simple inspection of the figure shows that the area of the original deposit must have been greater than the area of the remnant which has been left by erosion. This at once suggests the question how great we may reasonably suppose the original extension of the formation to have been. The majority of the geologists who have studied the Triassic formation believe that it was deposited in a number of isolated basins, and that the boundaries of the areas of deposition were not many miles removed in any case from the boundaries of the present areas of the rocks. This view substantially has been held by Percival, Dana, Davis, Emerson,

*Many of the specimens of ripple-marks, rain-prints, and tracks, are casts of the original impressions, with the relief exactly reversed, formed on the under surface of the overlying layer.

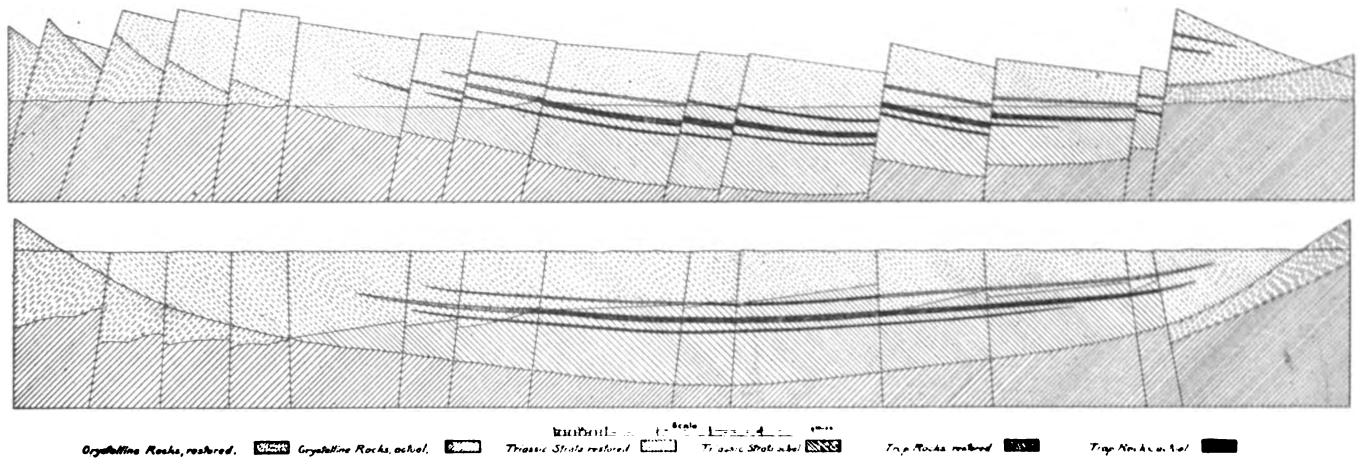


Fig. 2. Sections across the Connecticut Valley Triassic. The upper section shows the present attitude of the formation as tilted and faulted. The parts which have been removed by erosion are restored. The lower section shows the supposed attitude of the formation before the tilting and faulting. (The shading with parallel lines does not represent planes of stratification.) From Davis' paper in *Eighteenth Annual Report of U. S. Geological Survey*.

Newberry, Kümmel, and Shaler.* It has been maintained, on the other hand, by a few students of the formation, particularly by Professor I. C. Russell and Professor W. H. Hobbs, that the Triassic deposit once formed a continuous area from Nova Scotia (or at least from Massachusetts) to South Carolina, which has been broken into discontinuous areas by a vast amount of erosion.† The enormous amount of erosion demanded by this theory seems rather overwhelming to the non-geological reader; but the geologist appreciates so fully the unquestionable fact that vast erosion has taken place in this region, as in many other regions of the earth's surface, that he would find in that requirement no serious objection to the hypothesis in question. There seem to be, however, two somewhat serious objections to the hypothesis that the Triassic sandstones ever formed a continuous area. It is a little difficult to picture any geographical conditions which would produce a lake or estuary of fresh or brackish water of so prodigious extent. It would appear that a subsidence which would allow the formation of a continuous body of water of that extent would let in the sea somewhat freely. In that case marine fossils would naturally be expected to bear witness to the fact, but almost no marine fossils have been found. It is, on the other hand, easy to picture the occurrence of a number of estuaries, lakes, and marshes, along the Atlantic border, occupying hollows formed by folding or faulting of the older rocks. In such isolated bodies of fresh or brackish water, we might expect precisely such deposits to accumulate as are found actually to occur. A second objection to the hypothesis of a continuous deposit is found in the frequent occurrence of coarse conglomerates along the margins of the Triassic areas. Coarse conglomerates are rarely deposited except in the immediate vicinity of a shore line. In general, if we examine the deposits now in process of formation, by a line

* For summaries of opinion on this question, see Russell, *The Newark System*, ch. IX; Hobbs, *The Newark System of Pomperaug Valley*, p. 28; Hobbs, *Former Extent of the Newark System*, in *Bull. Geological Society of America*, vol. XIII, p. 139.

† The former continuity of the Dan River and Deep River beds in North Carolina was asserted by Kerr in 1875. See *Rep. Geological Survey of North Carolina*, vol. I, p. 141.

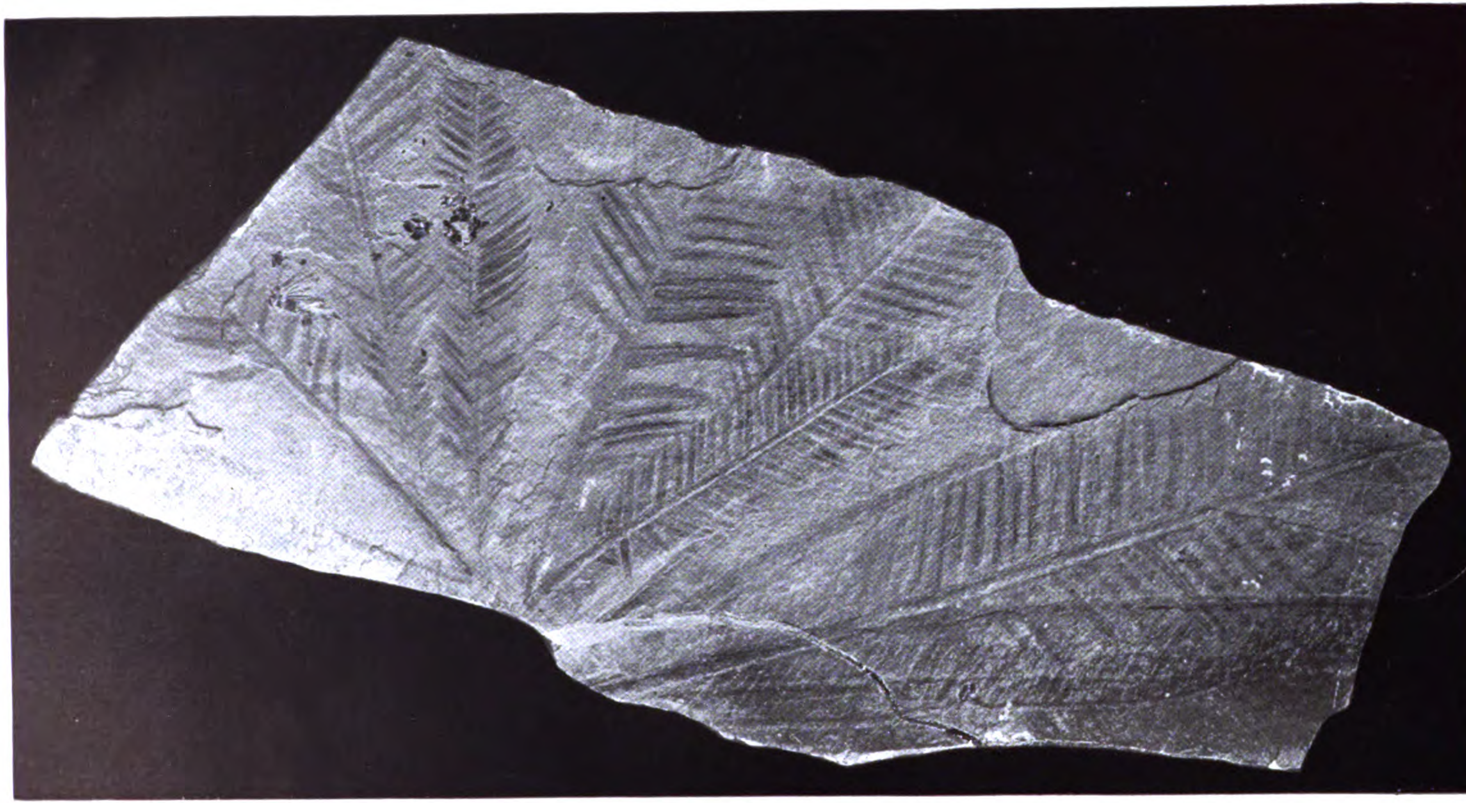
of soundings or dredgings extending from the shore line out into water of moderate depth, we shall find a gradual change from shingle and gravel through sand to fine mud. In the case of rocks of the Connecticut Valley, Percival, Emerson, and others have emphasized the fact of the occurrence of coarse conglomerates along the margins of the area, while fine sandstones and shales are found near the middle.* This would seem to indicate that the shore lines could not have been many miles from the present margins of the deposits. It is probable that, when any particular stratum was deposited, it was a coarse gravel at the edges of the estuary, but a fine sand or mud in the middle. The strong tidal currents which would have been likely to prevail in such estuaries would help to explain the movement of the very large bowlders in some of the fragmental conglomerates. It seems, therefore, on the whole, probable that the deposits in question were originally formed in isolated basins, whose extent was not very much greater than the areas now occupied by the rocks. In Connecticut, for instance, we may reasonably believe that the little area of the Pomperaug Valley was once continuous with the larger area of the Connecticut Valley; but it is not probable that the Connecticut area was ever connected with the New York-Virginia area.

FOSSILS.

Plants.— The strata of black shale which have been mentioned contain somewhat abundant remains of plants. This is especially true of the Richmond area, and of some of the other southern areas, where the conditions during part of the period of the deposition of the rocks were those of a marsh, and where the accumulation of vegetable material has resulted in the formation of beds of coal. With the exception of a few obscure and doubtful forms, the plants belong to four different groups. The Pteridophytes or Acrogens, the highest class of the flowerless plants, are repre-

* While I believe these writers are justified in asserting such a distinction between the marginal and the central parts of the formation, there are exceptions Gregory (*Farmington Folio*) has called attention to the occurrence of pretty coarse conglomerates north of Meriden and at Windsor, near the middle of the basin.

PLATE XVI.



OTOZAMITES LATOIR, DURHAM.

One-half natural size. Original in Museum of Wesleyan University. Photograph by W. M. Esten.

sented by the two groups of Ferns and Equiseta. The Gymnosperms, the lower of the two classes of the flowering plants, are represented by Cycads* and Conifers. Among the Equiseta it is noteworthy that the Carboniferous genus Calamites still survived. The general facies of the vegetation, however, is strikingly different from that of the Carboniferous, in the vastly greater development of Cycads and Conifers. The Gymnosperms were becoming the dominant group. On the other hand, the vegetation whose remains are preserved in these strata differs strikingly from the vegetation of the present time, in the complete absence of the higher class of flowering plants, the Angiosperms, which now dominate the field and forest.

Invertebrates.— The rocks have thus far afforded no Corals nor Echinoderms nor Brachiopods. The absence of these marine groups is correlated with the probable deposition of the strata in water which was fresh or at least brackish. A few species of molluscan shells have been found, some of which are believed to be fresh-water forms, more or less closely allied to the Unionidæ, or fresh-water mussels, of our present ponds and rivers. In Pennsylvania, indeed, it is believed that two species of the modern genus Unio have been recognized. The only Mollusk which has been found in the Connecticut Valley area was found in Wilbraham, Massachusetts, and has been referred to the genus Anoplophora, which is believed to represent an ancestral form from which the modern fresh-water mussels were derived.† A few shells from Pennsylvania are believed to have been marine. That occasional stragglers of marine forms should be present in an estuarine deposit is, on general principles, what might reasonably be expected. In the black shales of the New York-Virginia area and of some of the more southern areas have been found a few small Crustacea representing the two groups of the Ostracoids and the Branchiopods. In the Connecticut Valley area, both in Mas-

* A beautiful specimen showing the characteristic foliage of a Cycad is represented in Plate XVI.

† *Am. Journal of Science*, series 4, vol. X, p. 58.

sachusetts and in Connecticut, specimens have been found of the aquatic larva of a neuropterous insect. It has been described under the name of *Mormolucoides articulatus.* Some of the finer shales are marked with delicate impressions, which with much probability have been supposed to be tracks of Crustacea and Insects.

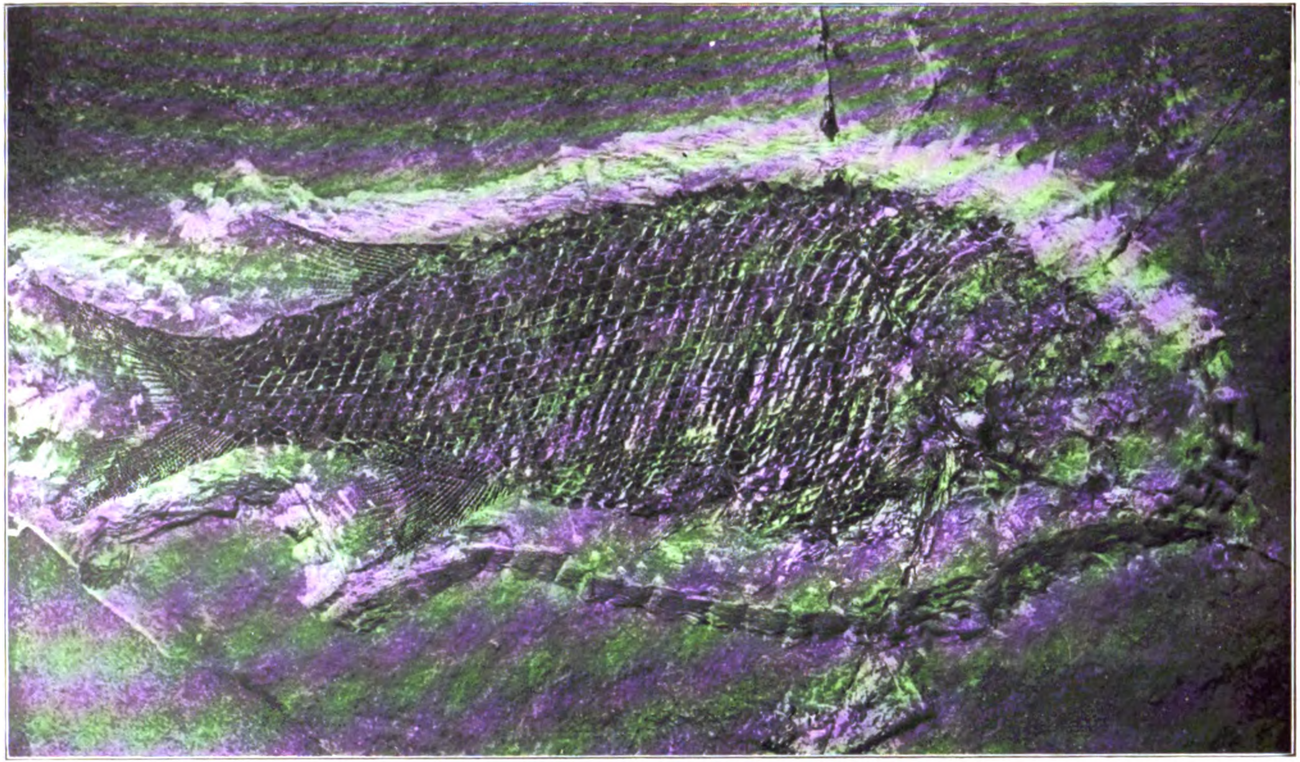
Fishes.— A number of species of Fishes have been found in the black shales, both in the Connecticut Valley area and farther south. All these fishes are included among the Ganoids.* Most of the fishes are Palæoniscoids† or Lepidosteoids. The Palæoniscoids are now entirely extinct, though the sturgeons represent an aberrant group somewhat closely related to them. The Lepidosteoids are represented by the gar-pike, or bony gar, of our western rivers. One genus of these fossil fishes belongs to the older and more primitive group of the Crossopterygians, a group which is represented among living fishes by a few species of Polypterus and Calamoichthys in the rivers of Africa. It is probable that the fossil fishes, like their nearest living representatives, were fresh-water forms.

Amphibians and Reptiles.— A number of finds of reptilian bones have been reported from the Connecticut Valley area and from Pennsylvania and North Carolina. Most of these are too fragmentary to admit of very satisfactory determination; yet these remains have sufficed to prove that the Amphibia are represented by remains of Stegocephala, and the Reptiles by remains of Crocodilians and Dinosaurs. Almost half a century ago Emmons described a pretty well preserved skull of a Crocodilian, *Rhytidodon* (*Rutiodon*) *carolinensis*, from the Deep River coal beds of North Carolina. In comparatively recent years a few discoveries of great importance have been made in the Connecticut Valley area. In 1884, near Manchester, Connecticut, was found

* This name is here used merely as a matter of convenience. The name Ganoid though widely current in the literature of the subject, does not represent a natural group.

† Catopterus is placed in this group by Zittel (in his *Grundzüge der Palaeontologie*), A. S. Woodward, and Eastman, though it shows close gradation toward the Lepidosteoids. A specimen of this genus from Durham is shown in Plate XVII.

PLATE XVII.



CATOPTERUS REDFIELDI, DURHAM.

Nine-tenths natural size. Original in Museum of Wesleyan University. Photograph by W. M. Esten.

Fig. 3. Restoration of *Anchisaurus colurus*. One-fourteenth natural size. From *Sixteenth Annual Report of U. S. Geological Survey*.

a considerable part of the skeleton of a Dinosaur, which has been named by Marsh *Ammosaurus major*. A few years later there was found in the same locality a nearly complete skeleton of another species of the same group which has been described under the name *Anchisaurus colurus*.* This specimen was so perfect as to afford Marsh satisfactory data for a restoration of the animal (Fig. 3). The animal must have been four or five feet in length. Remains of another species of the same genus have been found in the same vicinity. *Ammosaurus major* must have been an animal considerably larger than either of the species of Anchisaurus. To the genus Ammosaurus Marsh refers also the fragmentary remains found in 1865, at Springfield, Massachusetts, and described in Hitchcock's "Supplement to the Ichnology of New England," under the name *Megadactylus polyzelus*. All these forms belong to the suborder of Dinosaurs known as Theropoda. They were completely bipedal in their locomotion and were carnivorous. In 1896 was found in New Haven a considerable fragment of the dermal armor of a Crocodilian. It was described by Marsh under the name *Stegomus arcuatus*.† The entire animal may have been eight or ten feet long. Still more recently (1904) Professor Emerson has reported the discovery, at East Longmeadow, Massachusetts, of a nearly complete specimen belonging to an allied but much smaller species, *Stegomus longipes*.‡ The specimen is about six inches in length, measured to the base of the tail, most of which is missing. The Crocodilians which have been found in these rocks all belong to a suborder now entirely extinct.

While remains of reptilian bones have been comparatively rare, many layers of the deposits are crowded with tracks, which must have been made by Reptiles or Amphibians. The most abundant tracks are three-toed, and were apparently made by creatures whose locomotion was completely bipedal. In all probability these three-toed

* *Am. Journal of Science*, Series 3, vol XLII, p. 267; *Dinosaurs of North America*, in *Sixteenth Ann. Rep. U. S. Geological Survey*, part I, p. 147.

† *Am. Journal of Science*, series 4, vol. II, p. 59.

‡ *Am. Journal of Science*, series 4, vol. XVII, p. 377.

tracks are to be referred to the reptilian order of Dinosaurs. From the skeletons of Dinosaurs which have been found in considerable numbers in various parts of the world, we know that most of the members of the order must have been completely bipedal, and that the number of toes was often reduced to three, while in other species the number of toes was four, but the inner toe, the homologue of our great toe, was so small or inserted so far above the level of the others as to make no impression in the track. **Such a Dinosaur,** then, would make a single row of three-toed tracks, which is exactly the character of the most abundant tracks in our Triassic formation. Fig. 4 represents perhaps the most common species of tracks of this type. It is believed by Dr. Lull to be the track of *Anchisaurus colurus.** The bones of the foot, represented in the figure in connection with the outline of the track, are those of *Anchisaurus colurus.* In other cases, associated with the large tracks supposed to have been made by the hind feet, are occasional smaller tracks, indicating that, while the creatures were mainly bipedal in their locomotion, they occasionally placed their fore paws on the ground. This was the case with *Otozoum moodii,* which was apparently the largest of all the animals whose tracks are found in the Connecticut sandstones. The tracks of its

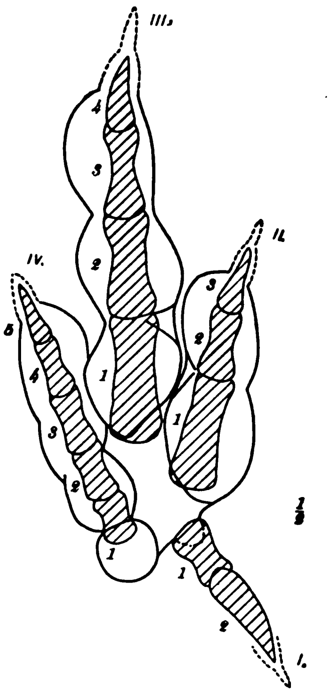


FIG 4. Track of *Anchisauripus dananus* (*Brontozoum sillimanium*). One-half natural size. The bones represented in the diagram are those of *Anchisaurus colurus.* From Lull, *Fossil Footprints of the Jura-Trias.*

* *Memoirs of Boston Society of Natural History,* vol. V, p. 487.

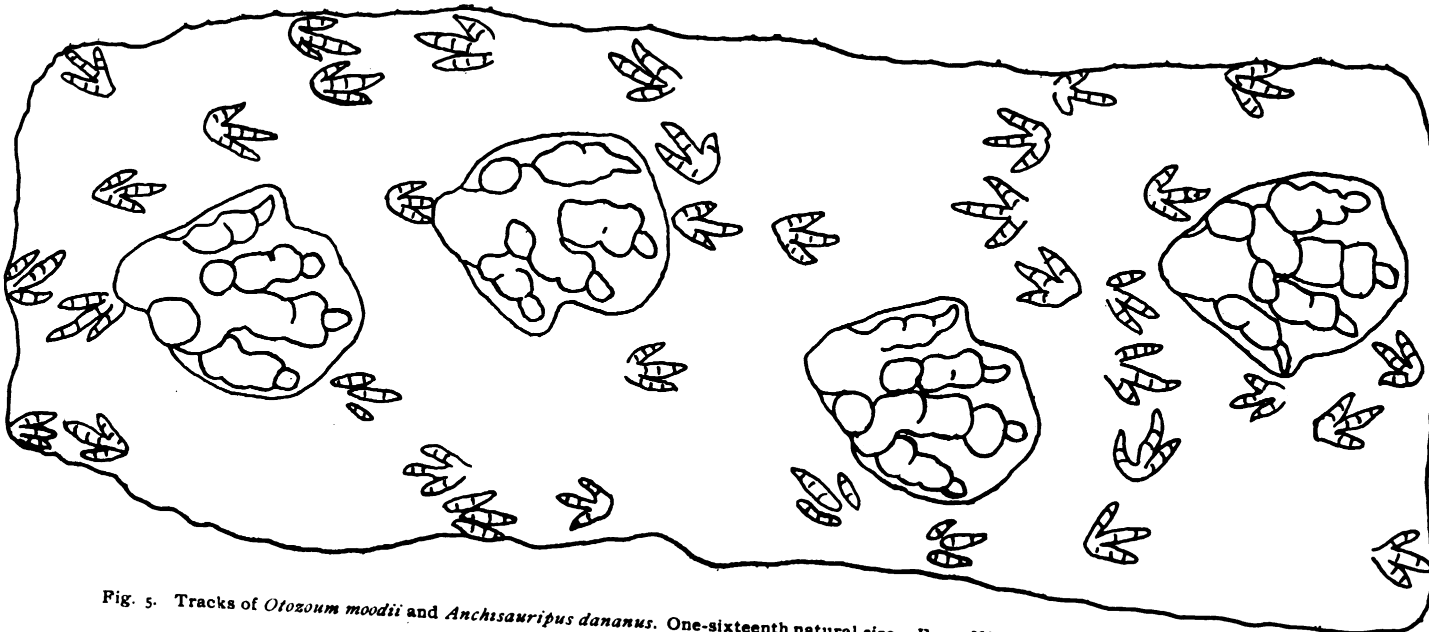


Fig. 5. Tracks of *Otozoum moodii* and *Anchisauripus dananus*. One-sixteenth natural size. From Hitchcock, *Ichnology of Massachusetts*.

hind feet are about twenty inches in length. Fig. 5 represents a series of these huge tracks, associated with several tracks of the more abundant *Anchisauripus dananus* (*Brontozoum Sillimanium*). While all the dinosaurian bones and teeth which have been discovered belong to the carnivorous suborder Theropoda, some of the tracks indicate animals whose toes were armed with blunt claws such as would seem unsuitable for a carnivorous animal. Dr. Lull has raised the question whether some of these tracks may not have been made by representatives of the Predentata — herbivorous, mostly bipedal, Dinosaurs.* No skeletons of Predentata have been found in any part of the world in any formation as early as the probable date of the Connecticut sandstone. Still other tracks — for the most part small ones — were made by creatures that were unquestionably quadrupedal, the separate impressions of the fore and hind feet being clearly distinguishable. One type of these small quadrupedal tracks, represented in Fig. 6, was probably made by little Crocodilians, like the one whose skeleton has recently been brought to light from Massachusetts.† A few of the tracks have been very doubtfully attributed to Turtles. Of course there is a considerable element of conjecture in the identification of animals on the evidence of tracks alone; and, while most of these tracks were doubtless made by Reptiles, it is not unlikely that some of them were made by Amphibians.

$\frac{1}{2}$

FIG. 6. Tracks of *Batrachopus* (*Anisopus*, *Anisichnus*) *gracilis*. One-half natural size. From Lull, *Fossil Footprints of the Jura-Trias*.

* *Op. cit.*, pp. 499, 544.

† Lull, *Am. Journal of Science*, series 4, vol. XVII, p. 381.

Birds.— The three-toed tracks which have just been mentioned are often popularly spoken of as bird-tracks; and that is not unnatural, for a three-toed bipedal track is very suggestive of a bird. It is, however, highly improbable that the class of Birds was in existence at the time of these deposits. No skeletons of birds have been found in any part of the world in any formations earlier than the upper part of the Jurassic. The formation in question must pretty certainly be referred to a considerably earlier date. It is, however, known, by the clear evidence afforded by skeletons, that, at the time when we must suppose these strata to have been deposited, Dinosaurs, which would make substantially bird-like tracks, must have been abundant. The gigantic size of some of the three-toed tracks is to some extent confirmatory of their reference to Dinosaurs rather than birds. The birds of the Jurassic era, and most of those of the Cretaceous, were comparatively small animals. Very large birds, like the modern ostriches, are not known to occur until a considerably later period. But many of the Dinosaurs in all Mesozoic time were gigantic.

Mammals.— No remains of Mammals have been found in the rocks of the Connecticut Valley. In North Carolina, however, have been found two little jaws, which are supposed to represent two different species and even two different genera of Mammals. These little jaws show a very peculiar type of molar teeth. In general, mammalian molars have the root divided into two or more fangs, while the simpler teeth of Reptiles show a single undivided root. In the teeth of these little fossils, the root is grooved, indicating a transition from the simpler form of the reptilian tooth to the completely divided fangs of the mammalian tooth. There has been, indeed, some doubt among paleontologists as to whether these little relics are truly mammalian or reptilian. In all probability they represent an extremely primitive type of Mammal, in which the characters of the more typical Mammals had not yet been completely evolved. It is a reasonable conjecture that, if we could study the complete anatomy of these little creatures, we might find some

of those same peculiarities of the skeleton and of the soft parts, particularly of the reproductive organs, which now characterize the duck-bill and the spiny ant-eater of Australia, the lowest and most reptilian of living Mammals. These modern Monotremes are toothless, at least in their adult condition; but it is altogether probable that the most primitive Monotremes, like the Reptiles, from which they must have been derived, possessed teeth.

THE AGE OF THE ROCKS.

The formation which we are considering has been thus far called provisionally Triassic. This seems the proper place for a word in regard to the evidence upon which the rocks are referred to that era. The fundamental criterion by which the relative age of stratified rocks is determined is the order of superposition of the strata. It is self-evident that every stratum is newer than the strata upon which it has been deposited, and older than any strata which have been deposited upon it; and upon this simple principle rests the whole scheme of the history of successive geological periods.

It is, however, obvious that the criterion of superposition can be employed only within the limits of particular districts of country. We cannot prove that a stratum in Connecticut underlies or overlies a stratum in England or in North Carolina. The only available means for determining the comparative age of rocks of different districts of country is found in the fossils which they contain. When the order of succession of strata has been made out independently in a number of districts of country, and the characteristic fossils of each stratum have been catalogued, there has been brought to light the profoundly significant fact that the order of succession in fossils is substantially the same all over the world. The series of fossiliferous formations is not indeed complete in any one district, but the order of those members of the series which are present in any particular district is never inverted. If, for instance, in one locality, as in England, an assemblage of fossils which we may call

A, B, C, is observed in one stratum, and in an overlying stratum is found an assemblage of fossils which we may call *D, E, F,* then nowhere in the world will the assemblage of fossils *D, E, F* be found underlying the assemblage *A, B, C.* The law which has been stated is an induction from a vast series of observations, and is abundantly verified as a general law, even though there may be isolated exceptions as regards the position of particular genera or species.

While this law has been developed inductively by the study of fossils, it may be recognized as probable *a priori* on the basis of the theory of evolution. It is a reasonable supposition that the broad outlines of the evolutionary history of plants and animals are due to causes operating simultaneously in all parts of the world. It is therefore probable that the broad outlines of evolutionary history have been the same in different continents or in different oceans. It is also reasonable to suppose that the vicissitudes of geological time have permitted or compelled migration in all sorts of directions, and by such migration the tendencies to divergent evolution in different parts of the earth's surface must have been largely held in check. It is, however, obvious that different groups of organisms must be of unequal value as criteria of geological age. Conditions of life in shallow seas adjoining the continents differ much less than conditions of life in different land areas. Hence there is much less tendency to faunal divergence in the case of marine organisms than in the case of terrestrial organisms. In the distribution of organisms at the present time, it may be observed that marine species are apt to have wider ranges than terrestrial, and that the difference between the faunas of different seas is much less than between the faunas of different continental areas. The same must have been true, in greater or less degree, in former geological times. It is also true, in general, that the higher and more complex organisms depend upon a more exquisite adaptation to particular conditions of existence than do the lower organisms. The differences between the mammalian faunas or different continents today are much more strongly

marked then the differences between the invertebrate faunas of different areas. For both of these reasons, therefore, the marine invertebrates are by far the most serviceable fossils in the discrimination of the age of deposits. The value of some groups of marine invertebrates as criteria of geological age is further enhanced by the fact that, owing to the conditions in which they live, and the large quantity of mineral matter in their tissues, they are preserved in fossil condition in immense numbers. Mollusks and brachiopods, crinoids and corals, are in general the most abundant fossils. It may be considered certain that our knowledge of the molluscan life of different periods is vastly less incomplete than our knowledge of avian or mammalian life.

Applying these principles to the formation which we are considering, we must say, in the first place, that the direct stratigraphic evidence in the case of the sandstones of the Connecticut Valley area gives us very little information. The Connecticut Valley sandstones rest unconformably upon the crystalline schists of the Highland areas. It is remarkable that in Connecticut actual contact has been observed only in a single locality — the ravine of Roaring Brook, in Southington.* The clearly marked unconformability of this contact shows that the sandstones were formed, not only subsequently to the original deposition of the schists, but subsequently to their tilting and metamorphism and to a considerable amount of erosion. But the destruction of fossils in the metamorphism of these crystalline rocks has left us destitute of any definite knowledge of their age. All that we can be sure of in regard to the crystalline rocks is that they are not later than the Paleozoic. The stratigraphy of the Connecticut Valley area affords no other indication of an upper limit of the age of the sandstones than the fact that they are overlain by Glacial drift. In some of the other areas, however, more definite information is afforded by the stratigraphy; and there is no reasonable doubt that the deposits in all the areas which have been enumerated† are substantially identical in age. In Nova

* See page 81, and Plate XIII.

† Page 162.

Scotia, the formation in question overlies unconformably Carboniferous strata. In New Jersey, the formation is overlain by the Potomac formation, which has been generally considered to be Lower Cretaceous, though it is possible that the lowest beds of the Potomac may belong to the uppermost part of the Jurassic. Stratigraphical evidence, then, leads to the conclusion that the red sandstones and associated rocks are not older than the Triassic and not later than the Jurassic.

We have already seen that, with the exception of a very few molluscan shells, no marine invertebrates are found in any of the areas of this formation. We are then practically destitute of those fossils which are of the greatest value in the determination of the age of the strata. Some of the strata of the European Triassic and Jurassic abound in marine fossils, but there are no means of correlating the sandstones in question with those marine strata. The best paleontological evidence which is available is afforded by comparison of the fossil plants, which occur abundantly in some areas of the formation, particularly in the Richmond area, with the fossil plants of some of the European strata. Such a comparison shows that the flora of these sandstones finds its nearest equivalent in that of the Keuper, the uppermost division of the European Trias. The indications afforded by the fishes and reptiles, though more scanty, are in harmony, so far as they go, with the evidence of the plants. It is therefore altogether probable that we are justified in applying to the Connecticut sandstones and the corresponding formations of other areas the name of Triassic. In the somewhat unsatisfactory condition of the evidence in regard to the age of these formations, some geologists have been accustomed to speak of them under the name Jura-Trias, thus avoiding a more definite expression of opinion in regard to the age. In the publications of the United States Geological Survey, the formation has been generally called the Newark formation, the name being derived from the city in New Jersey. It seems, however, best to apply to the rocks in question the name Triassic, though

it must be conceded that the evidence is not such as to exclude all doubt.

THE TRAP ROCKS.

Associated with the sandstones and other stratified rocks are extensive terranes of igneous rock, whose history and whose relations to the stratified rocks present many interesting problems. These igneous rocks are commonly known under the name of trap, the name trap denoting vaguely a dark, basic, rather fine-grained igneous rock, without regard to its definite chemical or mineralogical constitution.

Mineral Constitution.— With insignificant exceptions, to which reference will be made later, the igneous rocks of these Triassic areas present a remarkable degree of uniformity of character. They consist chiefly of augite and labradorite. While labradorite is the predominant feldspar, there is often present some other species of triclinic feldspar, which is andesine or anorthite, at least in most cases. Chrysolite (olivine) and apatite occur sparingly in the rock, and the former is sometimes altered to serpentine. Magnetite, the magnetic oxide of iron, occurs often in such abundance that the rock masses show themselves strongly magnetic. If a compass is moved about on the surface of one of our trap hills, the needle will often change its direction ninety degrees or more when moved only a few inches. The chemical work done in the laboratory of the New Jersey Geological Survey has shown that the trap rocks of that area sometimes contain not only magnetite, but metallic iron in minute grains.* The same is very probably true of the trap of other areas. Chlorite appears often as an alteration product in traps that are somewhat decomposed. The rock is generally fine-grained, but is almost always holocrystalline, or nearly so. Its solidification was too rapid to permit the coarse crystallization which characterizes the plutonic rocks, but not sufficiently rapid to form any considerable amount

* *Ann. Rep. State Geologist*, 1874, p. 56.

of glass. A rock such as is described above would be called a diabase or basalt. Typically, diabase is holocrystalline, while basalt contains at least traces of glass. Diabase shows in general a coarser crystalline grain than basalt. We shall see later (page 192) that some of the Connecticut traps are lava sheets, while others solidified below the surface in fissures in the sandstones. On the average, the extrusive traps are somewhat finer-grained than the intrusive, and the former are more likely to show a little glass when examined under the microscope; though specimens could doubtless be selected from the extrusive traps (especially from near the middle of the main sheet) which could not be distinguished from other specimens that might be selected from the intrusive traps. In recent publications, the United States Geological Survey has called the extrusive sheets basalt, and the intrusive dikes and sheets diabase. That usage will accordingly be followed in the present work and in other Bulletins of the Connecticut State Survey.

The following analysis (by Dr. J. H. Pratt) of the basalt of the main sheet, from Meriden, is taken from Professor Gregory's paper in the Farmington Folio of the United States Geologic Atlas: —

SiO_2	52.37
Al_2O_3	15.06
Fe_2O_3	2.34
FeO	9.82
TiO_2	.21
MnO	.32
MgO	5.38
CaO	7.33
K_2O	.92
Na_2O	4.04
H_2O	2.24
	100.03

In many localities the basalt of the extrusive sheets was rendered vesicular by the expansion of steam in the molten

PLATE XVIII.

TRAP COLUMNS, RABBIT ROCK, NORTH HAVEN.

Photograph by H. H. Robinson.

mass. The vesicles vary from microscopic dimensions to a diameter of several inches or even feet. The vesicles are generally filled or lined by minerals, often beautifully crystallized, which have been chemically deposited by percolating water. The rock is then said to be amygdaloidal. In the Connecticut Valley area, the minerals most frequently occurring in the cavities of amygdaloid are quartz, calcite, chlorite, prehnite, and datolite. The quartz is sometimes in drusy crystallizations, but sometimes it has the form of chalcedony or agate. Occasionally sulphuric acid, formed by oxidation of pyrite, has converted the calcite into gypsum or anhydrite. Zeolites appear to be rare in Connecticut, though occurring in great abundance in the amygdaloids of Nova Scotia and New Jersey. Asphaltum is occasionally found in the cavities of our amygdaloids.

Columnar Structure.— In the cooling of igneous rocks, it is often the case that cracks are developed, dividing the rocks into prismatic forms. This structure is commonly called the columnar structure, and is exhibited in great perfection in many localities of igneous rock. Theoretically, these shrinkage cracks, if the rock were perfectly homogeneous, and cooling advanced at an equal rate in all parts, should meet at angles of 120°, and divide the mass into hexagonal prisms. In spite of much irregularity, a tendency to hexagonal forms is often obvious. The direction of the axis of the columns should be perpendicular to the cooling surface. The trap rocks of the Connecticut Valley often exhibit the columnar structure in a rude and irregular manner. In a few places pretty regular columns are observed. The best example which has been noted in the state of Connecticut is at Rabbit Rock, near New Haven (see Plate XVIII). The Massachusetts geologists have called attention to good examples of columnar structure at Mt. Holyoke. Still finer examples of columnar structure in trap are to be seen in the vicinity of Orange, New Jersey.

Modes of Occurrence of the Trap.— The trap sometimes occurs in dikes, cutting across the strata at a high angle.

In the Connecticut Valley area, dikes seem to be especially abundant in the southern part of the area. Numerous small dikes and some large ones are observed in the vicinity of New Haven. The hills called Pine Rock and Mill Rock are formed by large dikes. The trap of Mt. Carmel appears to be a complex mass of dikes.

The larger masses of trap in the Acadian, the Connecticut Valley, and the New York-Virginia areas have the character of sheets; that is, instead of cutting across the strata at a high angle, they extend nearly or quite parallel with the associated strata, so that they seem to have the stratigraphical relations of truly stratified rocks. In Connecticut, we find two lines of outcrop of trap close to the western margin of the area, one of them extending from New Haven to Cheshire, and the other extending, with some interruption, from Avon to Granby (see Fig. 1, page 19). Whether these were ever continuous with each other is unknown. Farther east there may be traced, with many interruptions, the cause of which will be explained hereafter, the approximately parallel outcrops of three sheets of trap, extending across the state from East Haven to Suffield, not far from the middle of the Triassic area. The westernmost of the three was called by Percival the anterior sheet, and the easternmost the posterior sheet. The middle one is much thicker than either of the others, and is commonly spoken of as the main sheet. Davis estimates the thickness of the anterior sheet as about 250 feet, that of the main sheet 400 to 500 feet, and that of the posterior sheet 150 or 200 feet. The names anterior and posterior were given by Percival in a purely descriptive sense. The massive main sheet, being much more resistant to erosion than any other rocks in the Connecticut Valley, has been a controlling influence in the topography of the valley. Its outcrop is marked by a series of picturesque ridges, all having a gentle slope on the east side and a steep slope on the west side. This form results from the fact that the sandstones and the associated trap sheets have a gentle dip to the east. The topographical

effect of the action of erosion upon a gently dipping monocline composed of strata of unequal hardness, is always to develop unsymmetrical ridges, having a gentle slope following the dip, and a steep slope on the other side of the ridge.* It is not unnatural to call the steep side the face of the ridge, and the gentle slope its back. The westernmost of the trap sheets, cropping out under the steep face of the ridges formed by the main sheet, was accordingly called by Percival the anterior; and the eastern sheet, whose outcrops lie just to the east of the back slopes of the ridges formed by the main sheet, was called the posterior. It will appear hereafter that the names anterior and posterior have now acquired also a chronological significance, the westernmost of the three sheets being the earliest in date. Of these three sheets which extend through the middle of the Connecticut Valley, the anterior is confined to the state of Connecticut, but the main sheet and the posterior sheet extend into Massachusetts, at least as far as Mt. Holyoke. Whether the trap sheet which appears in the vicinity of Deerfield, Massachusetts, was originally a part of the main sheet of the southern Connecticut Valley, or an independent local eruption, is not certainly known.

Contemporaneous and Intrusive Sheets.— When a mass of igneous rock lies between two strata, with its bounding surfaces parallel or nearly parallel to the planes of stratification, it is obvious that there are two possible ways in which such a collocation of the rocks may be explained. It may be that, after the deposit of both the underlying and the overlying strata, the rocks were split apart by some strain, and molten rock flowed into the crack. Such a sheet is essentially of the same nature as a dike, each of these structures resulting from the intrusion of a molten rock into a crack in preexistent rocks. The only difference is that in one case the crack cuts across the planes of stratification, while in the other case the crack is parallel to the planes of stratification. Since planes

* See Fig. 10, page 205.

of stratification must always be planes of weakness in a rock, it is obvious that we may expect such sheets to be of frequent occurrence. Such a sheet is called an intrusive sheet. The other possible interpretation of a mass of igneous rock apparently interstratified with a series of sedimentary deposits, is that the igneous rock flowed out as a lava sheet, either upon the surface of the ground, or at the bottom of a body of water, after the deposition of the underlying strata, and before the deposition of the overlying strata. After a lava sheet had cooled and solidified, if it was originally under water, or if by subsidence it was carried below the water level, a subsequent series of strata might be deposited upon it. A sheet of igneous rock which flowed out thus upon the surface and was subsequently covered by sedimentary deposits of later date, is called a contemporaneous or extrusive sheet.

Criteria for the Discrimination of Contemporaneous and Intrusive Sheets.— It is obvious that in general a contemporaneous sheet, being exposed on its upper surface to the atmosphere or to a body of water, will cool more rapidly than an intrusive sheet of equal thickness, since the latter can lose heat only by the comparatively slow process of conduction through the rocks. An intrusive sheet, therefore, is apt to show a coarser crystalline grain than a contemporaneous sheet. A contemporaneous sheet may, in fact, cool so rapidly as to be glassy in parts. It is, however, obvious that the coarseness of crystallization must depend very much upon the thickness of the sheet and upon many local conditions. A thick contemporaneous sheet might cool more slowly than a thin intrusive sheet.

Since a contemporaneous sheet solidifies under little more than atmospheric pressure, it is apt to be rendered vesicular by the expansion of the steam which is contained in it. Subsequently the vesicles may be filled by the deposit of crystalline material from percolating waters, producing an amygdaloidal structure. If a contemporaneous sheet is of considerable thickness, the deeper portions of it will solidify under a pressure very much greater than that at the surface;

PLATE XIX.

TRAP CLIFF, AND BUILDINGS OF TRINITY COLLEGE, HARTFORD.

The contact of the trap with the underlying strata is of the type characteristic of extrusive sheets.
Photograph taken under direction of W. M. Davis for U. S. Geological Survey.

PLATE XX.

TRAP RESTING ON OBLIQUELY TRUNCATED EDGES OF STRATA, WEST ROCK, NEW HAVEN.

Type of contact characteristic of intrusive sheets.
Photograph taken under direction of W. M. Davis for U. S. Geological Survey.

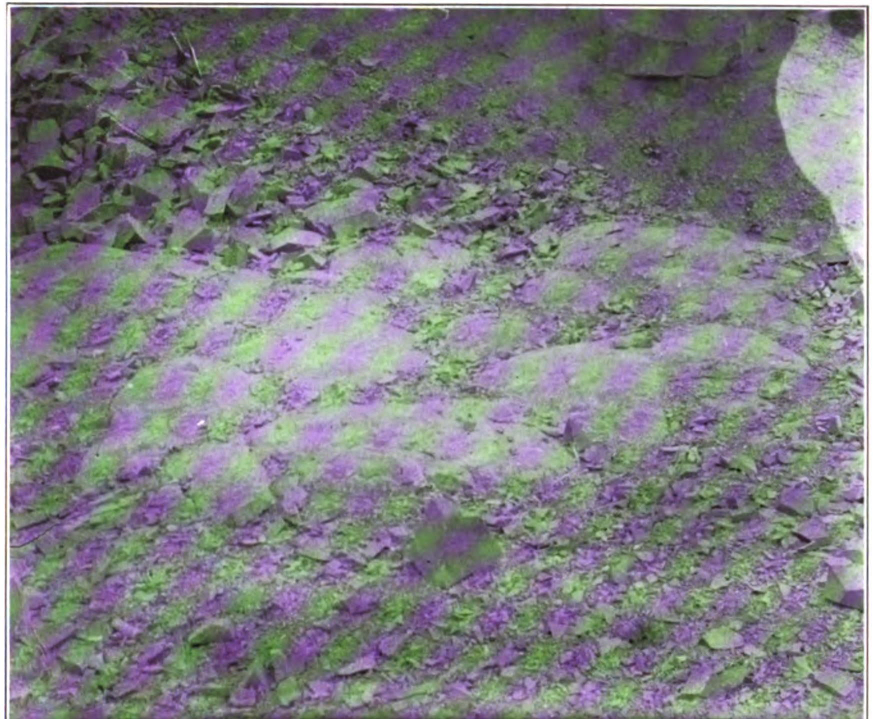
hence it is very commonly the case in contemporaneous sheets that the superficial portions are highly amygdaloidal while the deeper portions are much more compact. As a lava sheet spreads itself over the surface of the country, the more rapid motion of the superficial portions as compared with the deeper portions sometimes results in the under-rolling of a portion of the vesicular crust which has been already formed upon the surface. In this way it sometimes comes to pass that a contemporaneous sheet is amygdaloidal both at the top and at the bottom, while it is compact in the interior. Since all parts of an intrusive sheet solidify under a considerable pressure, the rock is generally not vesicular at all. In the exceptional cases in which portions of an intrusive sheet are amygdaloidal, the amygdaloidal character is not systematically limited to the upper and lower surfaces.

The surface of contact between a contemporaneous sheet and the underlying strata will usually be exactly accordant with the planes of stratification. There may be, of course, exceptions, in cases in which the surface of the strata had been exposed to erosion for some length of time before the outflow of the lava. In an intrusive sheet, on the other hand, it will seldom be the case that the surface of contact, either with the underlying or with the overlying strata, will be for long distances exactly accordant with the planes of stratification. In the great majority of cases, though the fracture may, in a general way, follow the planes of stratification, it will here and there break across the strata, following for short distances joint planes or irregular surfaces of feeble cohesion due to local variation in the texture of the rock. This distinction may be very strikingly illustrated by a comparison of the contact of the trap and the underlying sandstones in the bluff at Trinity College, in Hartford, with that at West Rock, New Haven, as shown in Plates XIX, XX. In the former case, the contact, which is exposed for a long distance in the face of the bluff, is perfectly accordant with the stratification, while in the latter the contact cuts obliquely across a considerable series of layers.

Stratified rocks are apt to undergo a greater or less amount of metamorphism in contact with molten rock. The change may be simply induration. Oftentimes there is a change of color. The shales of the Connecticut Valley often assume a peculiar purple color near the contact with the trap. Sometimes a highly crystalline texture is developed in the sandstones. If the molten rock comes in contact with a mud still imperfectly consolidated, the expansion of the water into steam may give a vesicular character to the stratified rock, and the vesicles may come to be filled with crystalline minerals like the vesicles of an amygdaloid. It is obvious that an intrusive sheet will produce metamorphic changes upon both the underlying and overlying strata, while a contemporaneous sheet can metamorphose only the underlying strata.

If a contemporaneous sheet is poured out at the bottom of a body of water, the superficial crust of igneous rock may become cracked and broken into fragments, and those fragments may be rolled about by currents in the water. They may thus come to be mingled with the mud or sand or gravel derived from other sources which the waters are transporting and depositing. It is accordingly often the case that a contemporaneous sheet is immediately overlain by a conglomerate consisting largely of fragments of the igneous rock itself. It would be, of course, impossible for a similar condition to be developed at the top of an intrusive sheet. The molten rock of an intrusive sheet, on the other hand, may often flow up into cracks in the overlying strata, thus forming little dikes. A very striking example of this is to be seen in the ravine of Roaring Brook in Cheshire. The criteria mentioned in this paragraph are in general more perfectly unmistakable than most of the others. The coarseness of grain of the igneous rocks, the amount of vesicularity, the degree of induration or apparent alteration in the sedimentary rocks, may vary greatly as the result of a variety of causes. But a conglomerate overlying a sheet of igneous rock and containing fragments of that rock affords indubitable evidence that the

PLATE XXI.



SURFACE OF LOWER LAVA FLOW, MAIN TRAP SHEET, MERIDEN.

Upper Lava Flow is seen in background.
Photograph by J. R. Harris.

sheet is contemporaneous; and dikes proceeding from a sheet of igneous rock into the overlying strata afford equally indubitable evidence that the sheet is intrusive.

A contemporaneous sheet may often be double or multiple. A certain amount of lava may flow out, and subsequently a second outflow may take place over the already consolidated surface of the former. In the great trap quarry at the southeastern corner of the Hanging Hills in Meriden, it is clearly seen that the main sheet is double. The compact trap of the upper flow can be seen resting upon the hummocky surface of the highly amygdaloidal trap, which forms the top of the lower flow, as shown in Plate XXI. A band of decomposing amygdaloidal trap, underlain and overlain by compact trap, reveals in like manner the fact of a double flow in the posterior sheet near Westfield, just north of the Sebethe River. It is obvious that such a multiple structure would be impossible in an intrusive sheet.

Since outflows of lava are often associated with explosive eruptions, it follows that a contemporaneous sheet may be locally associated with or replaced by tufaceous deposits. In southern Connecticut, the anterior trap sheet in the parts corresponding to Salstonstall Mountain and Totoket Mountain is associated with very extensive tufaceous deposits. In the vicinity of Mount Holyoke in Massachusetts, the trap of the posterior sheet is overlain by very extensive tufaceous deposits. It is needless to say that an intrusive sheet cannot be associated with ashes or tufa or other evidences of explosive eruption.

When a contemporaneous sheet runs over the surface of soft mud at the bottom of a body of water, it may happen that the contact of the water will chill the bottom of the lava sheet, so as to form a crust, above which the lava is still liquid. The heat of the lava may then produce so much steam in the mud under the crust that it will here and there burst up through the crust, so that a mass of mud and water and fragments of the already solidified igneous rock may be carried up into the interior of the molten mass. The very peculiar structure displayed in the anterior trap sheet

west of Lamentation Mountain in the northern part of Meriden is perhaps best explained in this way, though the locality was first described as an ash bed, and is popularly known in the vicinity as "the volcano."* It is obvious that no similar structure could be produced in connection with an intrusive sheet.

The application of these criteria has established beyond a reasonable doubt the character of the trap masses of the Connecticut Valley. The accumulation of the evidence has been the work of much labor, since, as can easily be seen from the general statement given above, the criteria for the distinction of contemporaneous and intrusive sheets are mainly to be found at the contact with the overlying strata, and, in the Connecticut Valley, these upper contacts are in most places concealed by drift and vegetation. Careful search, however, has revealed these upper contacts in a good many localities. The trap sheet near the western border of the Triassic formation in southern Connecticut, extending from West Rock, New Haven, to the north end of Gaylord's Mountain in Cheshire, is very certainly intrusive. East Rock, New Haven, is also unquestionably intrusive. The same is true beyond reasonable doubt, though the evidence is not quite so complete, in regard to the trap sheet on the western border of the formation in northern Connecticut, extending from Avon to Granby. On the other hand, there is no reasonable doubt that the three trap sheets which may be traced across the whole breadth of Connecticut, from Saltonstall Mountain in East Haven to Suffield, and two of which can be traced still farther to Mount Holyoke in Massachusetts, are contemporaneous. Upper contacts have been discovered in a number of localities on the back of each of the three sheets — the anterior, the main, and the posterior. Their amygdaloidal upper surfaces, the complete absence of any metamorphism of the overlying sandstones, and the frequent occurrence of a trap conglomerate immediately overlying the trap sheet, have left no doubt in

* Emerson, *Diabase Pitchstone and Mud Enclosures of the Triassic Trap*, in *Bull. Geological Society of America*, vol. VIII, pp. 66, 72.

the minds of most geologists who have studied the phenomena.*

The Traps of New Jersey.— The investigations of Darton and others have shown that the great sheet of the Palisades on the west bank of the Hudson is intrusive, while the trap of the Watchung Mountains farther west is contemporaneous. The complementary relation of the positions of the intrusive trap in Connecticut and in New Jersey is highly significant. As the Connecticut strata dip to the east and the New Jersey strata to the west, the lowest strata of the formation are found along the western border in Connecticut and along the eastern border in New Jersey. In each case the great intrusions of igneous rock have taken place in the lower strata of the formation.†

Age of the Intrusive Sheets.— It is obvious that the contemporaneous sheets belong to an epoch which, roughly speaking, is not far from the middle of the period in which the sandstones were deposited. They are, of course, newer than the underlying strata, older than the overlying strata. But the relation of an intrusive sheet to the stratified rocks fixes a limit for the time of intrusion only on one side. We know that the intrusive sheets must be later than the overlying strata, but how much later does not appear. While it is impossible to determine the age of the intrusive sheets as definitely as that of the contemporaneous sheets, there is a strong probability that the age of the intrusive sheets is not very different from that of the contemporaneous sheets. The fact that in Connecticut the intrusives are found only in the sandstones underlying the anterior contemporaneous sheet, is very suggestive of the conclusion that the date of these intrusives was prior to that of the deposition of the upper strata of the formation. Davis has shown that in all probability the intrusive sheets are dislocated by some of

* For details in regard to localities, the student may refer to the papers of Davis; particularly in *Eighteenth Ann. Report U. S. Geol. Survey*, vol. II, pp. 48-77, and in *Bull. Museum of Comparative Zoölogy*, vol. XVI, pp. 99-138.

† The intrusive trap of Sourland Mountain in New Jersey, though not near the eastern border of the formation, is associated with strata probably below the middle of the series, brought up to the surface by a great fault. Kümmel, in *Ann. Rep. State Geologist of New Jersey*, 1897, pl. II.

the same faults which have dislocated the contemporaneous sheets. Those faults were probably produced, at least for the most part, at the same time at which the strata were elevated and tilted and the old estuary was finally drained. This line of reasoning would show, of course, that the intrusive traps cannot be later than the time of the tilting and faulting. It is then a probable conclusion, though the evidence is not altogether conclusive, that the date of the most of the intrusions is not far from the date of the contemporaneous eruptions.

Volcanoes.— It is certain that there are no volcanoes in Connecticut at present. Whatever volcanoes may have existed, have long since been buried beneath later deposits or removed by the processes of erosion. The outpouring of vast sheets of lava may take place along great fissures without the formation, at least on any considerable scale, of volcanic cones. In recent times some of the lava eruptions of Iceland seem to have been of this type. Fissures have opened a score of miles or more in length, and the lava has poured out in vast floods without any explosive forms of eruption. The extensive tufaceous deposits, however, which are found in connection with the anterior sheet in southern Connecticut, and in connection with the posterior sheet in the region of Mount Holyoke, suggest the probability that volcanic cones of greater or less extent were formed at the time of these eruptions. It is a noteworthy fact that dikes are very abundant south of Cheshire and Wallingford, while they seem not to occur in the northern part of the formation within the state of Connecticut. It is a plausible conjecture that some of these dikes may mark the sites of old volcanoes, though the cones themselves have long since disappeared. Through some of the fissures now marked by dikes there may have come to the surface not only flows of lava, but explosive discharges of ashes, which may have accumulated locally in cones of considerable height. Davis has plausibly conjectured that the trap mass of Mt. Carmel may have been the root of a large volcano.* Emerson has

*_Eighteenth Ann. Rep. U. S. Geological Survey_, vol. II, p. 44.

shown strong evidence for the belief that in the vicinity of Mount Holyoke the closing phase of igneous activity consisted in discharges from typical volcanic cones. The plugs of lava marking the site of the volcanic chimneys may still be recognized, though the cones have been removed by erosion.*

It may be proper to remark in this connection that the topography of the trap rocks in the Connecticut Valley has no relation whatever to the form of volcanoes. As has been already remarked,† the outcrops of the main sheet, and to some extent the outcrops of the feebler anterior and posterior sheets, are marked by unsymmetrical ridges, having a gentle slope in the direction of the dip and a steep slope on the other side of the ridge. Substantially the same form is seen in the ridges which were formed by the intrusive sheets of trap. It is then entirely independent of the question whether the trap is contemporaneous or intrusive. It has, in fact, no relation to the igneous origin of the trap. It is simply an erosion form resulting from the fact that the trap is more resistant than the sandstones and shales with which it is associated. If the trap were replaced by a peculiarly hard stratum of grit or quartzite, the topographical form would be exactly the same. In fact, the form of the trap ridges in Connecticut is strikingly similar to that of some ridges in the Pennsylvania Appalachians formed by the Medina sandstone.

Peculiar Igneous Rocks.— While in general the trap rocks of the Connecticut Valley, whether contemporaneous or intrusive, show a remarkable uniformity in chemical and mineralogical constitution, a few cases have been observed of dikes of very different types of rock. In East Haven there are small dikes of a much more acidic type of rock, consisting chiefly of feldspar, and described by Hovey as a keratophyre.‡ In Middlefield, near the village of Baileyville, there is a dike of an exceedingly basic rock, consisting

* *Geology of Old Hampshire County*, pp 411, 481.
† Page 32.
‡ *Am. Journal of Science*, series 4, vol. III, p. 287.

chiefly of augite, porphyritic with large crystals of augite and hornblende.*

VEINS AND OTHER SECONDARY DEPOSITS.

The sandstones of the Connecticut Valley are traversed in various places by veins of barite, often associated with copper ores. The largest barite veins are those of Cheshire. At that locality malachite, chalcocite, bornite, and native copper occur in the barite, but in quantities too small to be of any economic significance. The veins, however, were formerly worked for the barite itself, which was mixed with white lead in the manufacture of white paint. At Edgewood (formerly Whigville), near Bristol, copper ores have been found in considerable quantity, partly in the sandstones and partly in the crystallines, near the contact of the two formations. The workings at this locality were commenced on a somewhat larger scale in 1836, though some work had been done before the close of the eighteenth century. After an interruption of many years, the work was again prosecuted between 1888 and 1895. The Bristol copper mine has been famous for the splendid crystals of chalcocite which it has yielded. Copper ores, chiefly chalcocite and malachite, occur in East Granby, disseminated through a gray sandstone. A company for the working of a mine at this locality was chartered as early as 1709. For about sixty years in the latter part of the eighteenth and the early part of the nineteenth century, the old mine was used as a prison. The working of the mine was resumed about 1830 and prosecuted for a time. Native copper has been found at a number of localities in thin plates or threads in the trap. Masses of native copper have been found occasionally in the drift, which in all probability were derived from the Triassic rocks of Connecticut or Massachusetts. Among the finds of this sort reported are a mass of ninety pounds found in Hamden in the latter part of the eighteenth century, and one of two hundred pounds found near New Haven.

* *Bull. Museum of Comparative Zoölogy*, vol. XVI, p 239.

It is noteworthy that the reported occurrences of copper ores in Connecticut are all from the west side of the area. None of the occurrences are in strata above the main sheet of the contemporaneous traps. Closely parallel with this is the distribution of copper ores in the Triassic of New Jersey. Professor J. V. Lewis writes:—"The copper lies in irregular areas of the shales, between the intrusive and the lowest extrusive sheet. Sometimes it lies on the back of the intrusive, sometimes at the bottom of the earliest extrusive, but frequently it occurs with small dikes, or no visible trap at all, in the intervening areas of shales."

In several particulars the geological and mineralogical relations of the copper ores in Connecticut are analogous to those of the copper in the Lake Superior region. In each case there is an alternation of fragmental strata with contemporary sheets of igneous rock. In each case the copper ores are found partly in veins, and partly irregularly disseminated in both the sedimentary and the igneous rocks. In each case the occurrence of native copper is noticeable, though in the Connecticut area the amount of native copper as compared with other copper ores is much smaller than in the Lake Superior region. In two respects, indeed, the two regions are markedly different. The Lake Superior rocks are believed to be pre-Cambrian, and are, therefore, vastly more ancient than the rocks of Connecticut. Economically, the Lake Superior copper deposits are of immense importance. In Connecticut, on the other hand, none of the localities where mining has been attempted have yielded sufficient return to justify the continuance of operations; and most of the occurrences of native copper are noticeable merely as mineralogical curiosities. The analogy of the two formations in so many respects suggests that the cause of the copper deposits is probably the same in both cases. In each case it seems probable that the copper was brought up from a subterranean source in the igneous rocks, and that it has been subsequently concentrated in veins and local impregnations of the rocks by the chemical action of subterranean waters. As to the date of the formation of the

veins and other secondary deposits, we have no definite knowledge. It is, however, natural to associate these formations with the epoch of uplifting and faulting which followed the deposition of the sandstones.*

DEFORMATION.

There is reason to believe that the Connecticut Valley was defined as a geosynclinal trough between uplifts of Archæan rocks before the beginning of Paleozoic time.† The early history of the region is, however, obscure because of the imperfection of our knowledge of the age of the crystalline rocks. In the first chapter of this paper, an attempt has been made to picture the condition of the Connecticut Valley at the beginning of the Triassic.‡ At that time the Connecticut Valley trough is supposed to have been a shallow estuary, into which was carried by rivers the debris from the more or less degraded but still perhaps lofty mountain regions to the east and west.

As it is certain that all the Triassic strata were shallow-water deposits, and that, nevertheless, the strata have accumulated to a thickness of thousands of feet, it is obvious that the bottom of the trough must have been gradually sinking during the period in which the deposition was in progress. Such a gradual subsidence of the bottom of a trough may be effected either by folding or by faulting, or by some combination of the two actions. The fact that in general the dips of the sandstones are somewhat higher on the western than on the eastern side of the valley, suggests the probability that the subsidence during the Triassic era was effected, in part, at least, by a gentle downfolding of the crust. If such a movement took place, the strata on the

* Professor W. M. Davis writes in regard to the barite veins, that the barite "occurs at various points associated so closely with the faults that it may be safely stated as later than the eruptions, and associated with the tilting and faulting, or of still later date." Professor J. V. Lewis writes in regard to the copper ores of New Jersey: "I am pretty strongly inclined, at the present stage of the investigation, to consider the copper deposits as contemporaneous with or following closely upon the intrusion of the Palisades sheet, and the Rocky Hill, Sourland, and other sills to the southwest, and considerably later than the surface flows of the Watchung Mountains, possibly even as late as the disturbances that tilted and faulted the Triassic strata."

† *Dana, Manual of Geology*, 4th edition, p. 461.

‡ Page 24.

west side of the trough would have acquired a slight easterly dip before the movement at the close of the Triassic by which the whole formation was tilted. The western strata should therefore at the present time show a somewhat steeper easterly dip than the eastern ones.

Post-Triassic Movement.— At the close of the Triassic the character of the movement changed. The region was elevated above the sea level, and the estuary was drained. The elevation was greater on the west side than on the east, so that, apart from local irregularities, the strata in Massachusetts and Connecticut show a monoclinal structure dipping to the east.

While the general attitude of the Triassic strata in the Connecticut Valley is that of a monocline, careful study has revealed a considerable amount of local irregularity. In some places a crumpling of the strata into shallow boat-shaped or dish-shaped synclines is observed. This synclinal arrangement is the cause of the very strong curvature in the outcrop of the main trap sheet in the ridges of Saltonstall Mountain and Totoket Mountain.* Between these two synclines an anticline brings the underlying shales to the surface. In each of these cases, the eastern side of the boat, as we shall see hereafter,† was carried up by a fault above the level of erosion of the country, and so has been removed. A similar boat-shaped syncline, though less strongly marked, is indicated by the curvature in the ends of that long section of the main trap range extending from the Hanging Hills of Meriden to Mount Holyoke. The syncline of Totoket Mountain is further complicated by a transverse anticlinal crumple, which divides the posterior trap sheet into two parts, bringing up between them the underlying strata. A well-marked anticlinal axis shows itself, trending from west-northwest to east-southeast, in Wethersfield and Rocky Hill. By means of this anticlinal flexure the posterior sheet corresponding to Cedar Mountain is divided into two parts, the northern part with the associated stratified rocks

* See map, Fig. 1, page 19.
† Page 213.

dipping to the northeast, and the southern part dipping to the south. Careful study reveals a good many local irregularities of dip; yet, in spite of all these minor irregularities, it remains broadly true that the attitude of the strata is a monocline with a dip of 15° or 20° a little south of east.

Faults.— One of the important discoveries which we owe chiefly to Professor Davis is the detection of a large number of faults in the Triassic strata, in some of which there was a differential movement amounting to more than a thousand feet. The existence of extensive faults in the strata is rendered *a priori* probable by the immense thickness which it would otherwise be necessary to assign to the formation. A simple inspection of Fig. 7 will show the

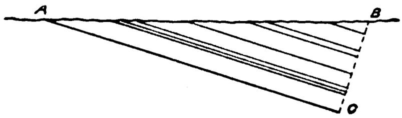


Fig. 7. Method of Estimating the Thickness of Strata.
BC (thickness of strata)—*AB* (breadth of outcrop) × sine *A* (sine of angle of dip).

method of estimating the thickness of strata. *AB* in the figure represents the breadth of the formation measured in the direction of the dip; and it is obvious that, if there has been no dislocation of the strata, the thickness of the strata, *BC*, will be equal to *AB* multiplied by the sine of the angle of dip (the angle *A*). If we proceed to apply this mode of calculation to the Triassic of the Connecticut Valley, we get a very surprising result. In some parts of the valley the formation has a breadth of more than twenty miles; and, as we have already seen,* it is certain that the original breadth of the formation must have been somewhat greater than it is at present, since erosion must have removed more or less from the edges of the area. The natural sine of 20° is a little more than one-third, and even that of 15° is more than one-fourth, so that this geometrical construction would require a thickness of strata amounting to from five to eight miles. The subsidence of a trough probably not

* Page 167.

much more than a score of miles in breadth to a depth of even five miles, though it cannot be called impossible, would certainly be *a priori* improbable. The hypothesis of ex-

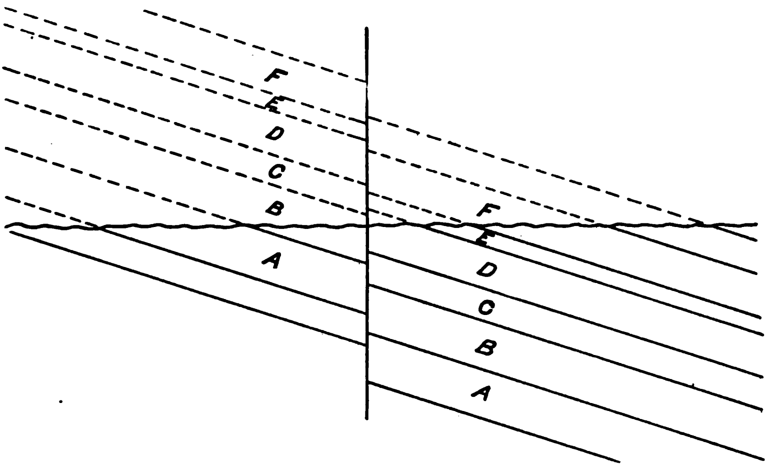


Fig. 8. Fault with dip side going down. Stratum *C* has no outcrop.

tensive faults is the only one by which we can be relieved of this demand for an enormous thickness of strata. An inspection of Figs. 8 and 9 will show that the effect of faults

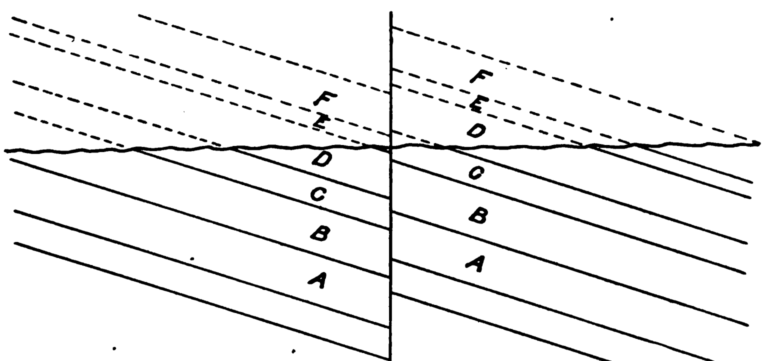


Fig. 9. Fault with dip side going up. Strata C and D have two outcrops.

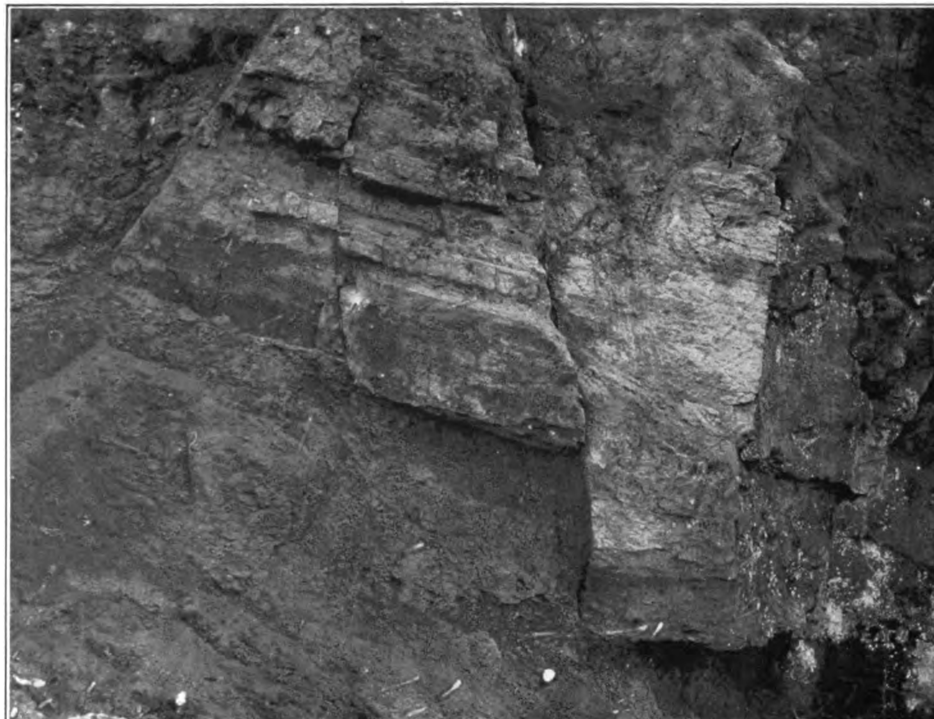
upon the outcrop of strata varies according as the dip side or the outcrop side of the fault goes up. In each of these figures the surface of erosion is indicated

by an irregular line approximately horizontal, and the parts of the strata removed by erosion are indicated by dotted lines. Fig. 8 shows that if the dip side (*id est,* the side toward which the strata dip) goes down, more or fewer of the strata fail to reach the surface and to show outcrops. On the other hand, if the dip side of the fault goes up (as shown in Fig. 9), more or fewer of the strata come to the surface twice and present outcrops in two different places.* It is obvious, then, that the existence of faults, if due allowance were not made for them, would vitiate the computation of the thickness of a formation based upon its breadth and its angle of dip. Faults in which the dip side went down would diminish the breadth of the formation and would make the estimate of its thickness too small. Faults in which the dip side went up would exaggerate the breadth of the formation and make the estimate of the thickness excessive. If, then, there are, in the Connecticut Valley region, a number of faults in which there has been relative elevation on the east side, the astonishing estimate of a thickness of five miles or more, which we have provisionally reached, would be shown to be largely in excess of the truth.

Evidences of Faults.— But belief in the existence of numerous faults, with upthrow in the large majority of cases on the east, does not rest merely upon *a priori* conjectures. In the first place, there are a good many natural or artificial sections of the strata, exposed in ravines, quarries, roadside cuttings, and other places, where faults can be directly seen. The strata, as shown in plate XXII, on opposite sides of the crack do not match. In most of the cases where faults can thus be seen in an exposed section, the amount of the throw of the faults appears to be only a few inches or a few feet. In some cases, it is impossible to recognize corresponding layers on opposite sides of the crack, and therefore impossible to make any estimate of the amount of throw. But there is no reason to believe that the

* These rules are reversed when the plane of the fault lies in the acute angle between the horizontal plane and the plane of stratification.

PLATE XXII.



FAULTS IN SANDSTONE, MERIDEN.

Photograph taken under direction of W. M. Davis for U. S. Geological Survey.

throw is at all considerable in any of these visible faults.

In some cases, the presence of a fault is indicated by a somewhat nearly vertical zone of shattered and more or less decomposed rock, a few inches or a few feet in width, cutting across the rocks exposed in a natural or artificial section. Such a breccia would naturally result from the grinding action of the rocks on opposite sides of a crack in slipping past each other. But, while the presence of a band of fault breccia would indicate a fault, it would not show the amount of the throw or the direction of the movement. Similar to the evidence afforded by fault breccias is that afforded by *slickensides,* which are more or less polished and striated surfaces produced by the mutual grinding where rocks have slid past each other. A little more indirect is the evidence of faulting that is afforded when we find, in following the outcrop of a rock along the line of strike, that the rock suddenly disappears and is succeeded by a rock of totally different character, though the actual contact of the two rocks is concealed by drift or vegetation. If we walk northward along the ridge of coarse sandstone just east of the Agricultural Fair grounds in Meriden, we shall find that the sandstone ridge presently disappears abruptly, and a great mass of trap rises directly before us. In this case no actual contact of the two rocks can be found; but the collocation of the rocks hardly admits any other interpretation than that of a fault.

An evidence of faults, which would not be in itself conclusive, but which helps to locate the position of a fault when its existence is indicated by other evidence, is found in abnormal dips. There is no sharp line of demarkation between faults and monoclinal flexures. If rocks are subjected to the action of forces which tend to make the portion on one side of a line move relatively upward and the portion on the other side of that line move relatively downward, the yielding may take place by the bending and stretching of a portion of the rock into a steeply dipping monocline along the line of differential movement, or the rocks may crack under the strain and a fault be produced.

The two actions may be combined, and we may have on the upthrow side of the fault a downward bending, and on the downthrow side of the fault an upward bending of the edges of the strata. The presence, then, of abnormal dips (" drag dips "), in situations where other evidences have led us to believe in the existence of faults, may serve for the more definite location of those faults.

Professor Davis has rightly urged, as an evidence of great faults in the strata, the immensely improbable series of coincidences in the stratigraphy which we should otherwise be compelled to assume. All along the Connecticut portion of the Triassic area, we find three sheets of trap presenting parallel outcrops, the lowest a comparatively thin sheet, the middle one a thick sheet, the upper one again a thin sheet. Between the lower or anterior sheet and the main sheet lies a series of rocks, mostly red shales, but including a thin stratum of limestone and a thin stratum of black shale with fossil fishes. Between the main sheet and the posterior sheet we find again a series of shales, mostly red, but including a stratum of black shale containing fossil fishes which are only in part specifically identical with those of the black shale below the main sheet. Below the anterior sheet and above the posterior sheet lie great accumulations of sandstones, shales, and conglomerates. Now, whether we make a section across Totoket Mountain or Higby Mountain or Lamentation Mountain or the long range which extends northward from the Hanging Hills, we encounter the same succession — underlying sandstones, then a thin sheet of trap, then shales, which in many different localities have been shown to include a stratum of limestone and a stratum of black fossiliferous shale, then a thick sheet of trap, then shales again, including a stratum of black fossiliferous shale, then a thin sheet of trap, then overlying sandstones. Now, the repetition of this identical stratigraphic series again and again is intelligible if we assume that the strata themselves are identical — that the thick sheet of trap in the Hanging Hills and in Lamentation and in Higby and in Totoket is the same sheet of trap, only

dislocated by faults, and that the successive members of the series, underlying and overlying the main trap sheet, are likewise identical. But on any other supposition it requires us to assume a series of coincidences in the order of sedimentation and igneous eruption which would be immensely improbable.

Topographic Effect of Faults.— An indirect but very satisfactory evidence of the faults in the Triassic formation is found in their topographic effects. Of course the primary effect of a fault upon the topography is to produce an elevation of the surface on one side of the crack above the other, showing, if the plane of the fault be somewhat nearly vertical, a more or less decided cliff. If the fault

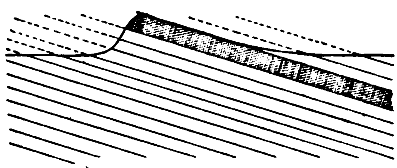


Fig. 10. Section showing Monoclinal Ridge developed by Erosion. The shaded stratum is more resistant than the others.

were accomplished by an instantaneous movement, the height of that cliff would be equal to the amount of throw of the fault. In subsequent time the tendency of erosion would be to diminish the height of the fault cliff and ultimately to efface it. Probably a fault cliff of the full height due to the throw of the fault nowhere exists, since it must be presumed that no large fault is ever produced by a single instantaneous movement, and the agencies of erosion would therefore be in action for a greater or less time before the fault was complete. As we have already seen,* the region of the Connecticut Valley was reduced to a peneplain in late Mesozoic time, and not a vestige of a fault cliff is to be found anywhere in the Connecticut Valley.

But, while the direct topographical effects of the faults in the Connecticut Valley have entirely disappeared, in-

* Page 28.

direct effects have been produced which we can very clearly recognize. In Fig. 10 is seen a section of a series of monoclinal strata. The shaded stratum is supposed to be more resistant to the agencies of erosion than the others. The section shows the topographical effect of such a structure. The outcrop of the strong stratum is marked by a ridge, with gentle slope in the direction of the dip and with steep slope on the other side.* It is needless to say that it makes no difference in the topographic effect whether the strong member of the stratigraphic series is a hard stratum of sedimentary rock or a sheet of igneous rock. In Fig. 11

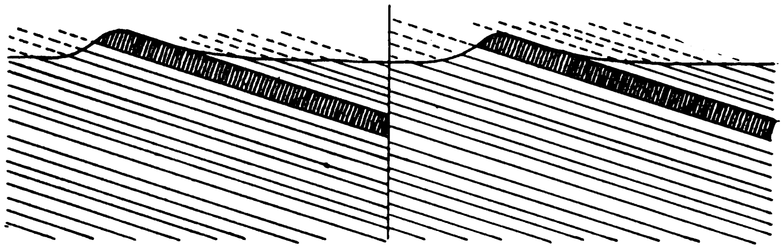


Fig. 11. Section showing two Monoclinal Ridges developed from the same Resistant Stratum, which has two outcrops by reason of a fault.

is seen the effect of a fault parallel to the strike and with upthrow on the dip side. A number of strata, among them the strong, ridge-making stratum, have their outcrops duplicated, and the section accordingly shows two ridges instead of a single ridge. It is evident that, if the fault is parallel to the strike, the two ridges thus formed by the outcrop of the resistant stratum will extend indefinitely as parallel ridges. But if the fault is at right angles with the strike, as shown in plan in Fig. 12, it is evident that each of the two parallel ridges will end abruptly at the fault plane without overlapping. Figs. 13 and 14 show the effect of diagonal faults. Where the rocks have been acted upon by a diagonal fault, the strong stratum develops, as before, two parallel ridges, each cut off on the fault plane. In Fig. 13, in which the dip side of the fault goes up, the two parallel ridges overlap each other for a certain distance; while in

* See also Plates II, XIX, XXIII.

Fig. 14, in which the dip side of the fault goes down, we have what we may call a case of negative overlap, the ridge due to the outcrop of the strong stratum disappearing for a certain distance. If we study a little more in detail the

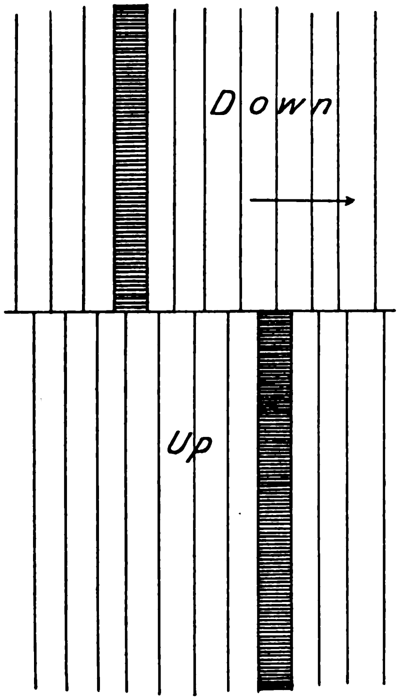


Fig. 12. Plan of Strata with Fault perpendicular to the Strike. The arrow indicates the direction of the dip. The parallel ridges which may be developed by erosion along the outcrops of a resistant stratum will be truncated at the fault line without overlapping.

conditions shown in Fig. 13, we shall see that the two ends of the overlapping ridges will not be exactly alike in their topographic expression. In the conditions represented in that figure — a dip to the east, and a northeast and southwest fault with upthrow on the southeast side — it is obvious that the acute angle shown on the plan at the south end of the strong stratum on the northwest side of the fault lies nearly in the line of the crest of the ridge; while, on

the southeast side of the fault, the obtuse angle shown at the north end of the southern part of the strong stratum lies in the line of the crest of the ridge, and the acute angle lies low down on the back of the ridge. The effect of this arrange-

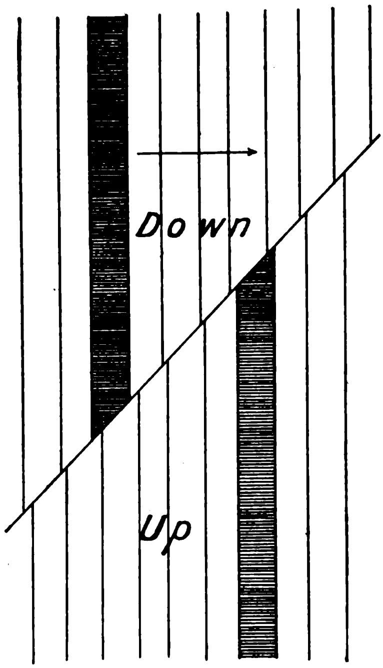


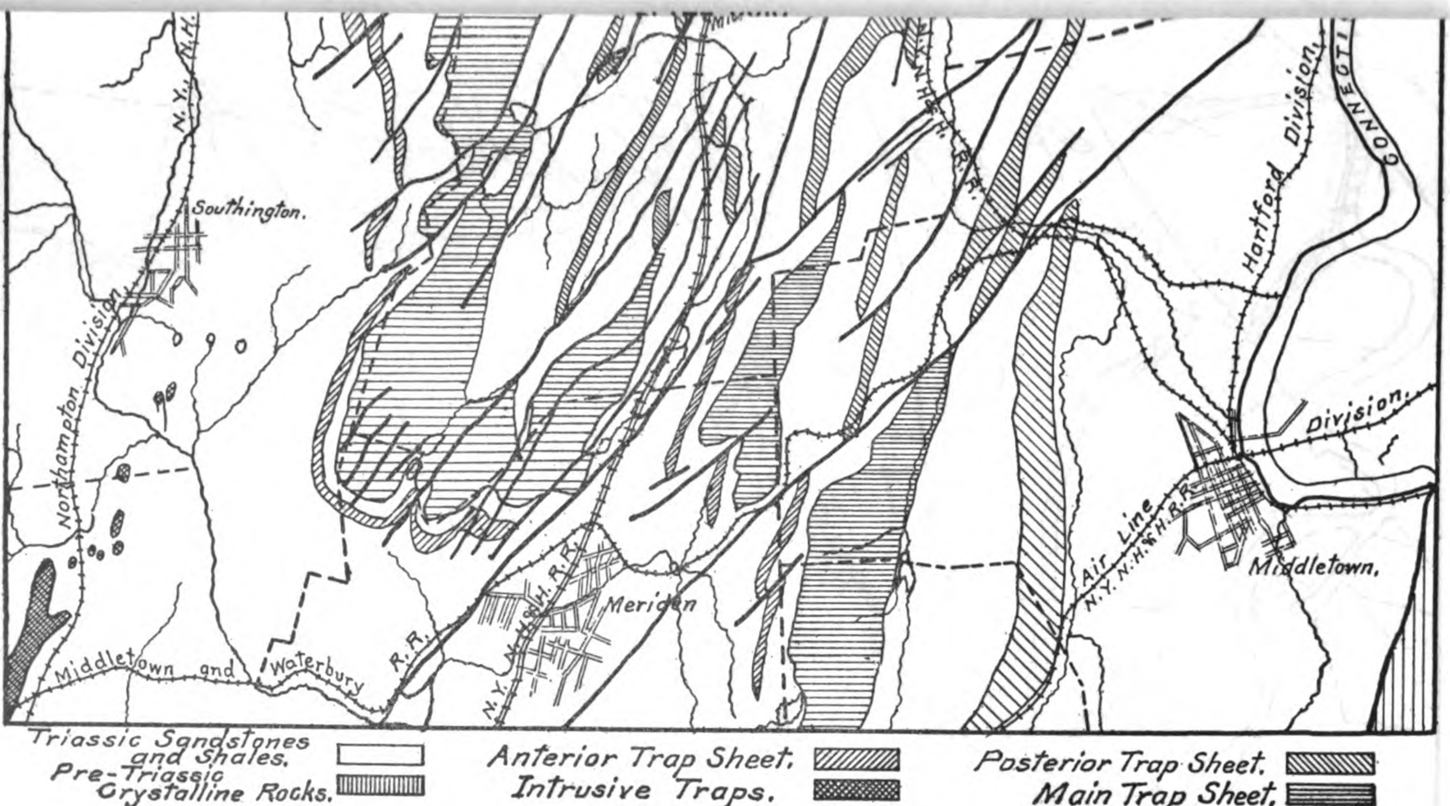
Fig. 13. Plan of Strata with oblique Fault and with the dip side going up. In this case the parallel ridges developed along the outcrops of a resistant stratum will overlap.

ment would be that, in such a case as is represented in the figure, the ridge on the north side of the fault must end southerly in a bold bluff, while the ridge on the south side of the fault must end northerly in a long trailing slope. A striking illustration of this last point may be seen in comparing the tapering north end of Higby Mountain with the bold southern cliff of Chauncey Peak (the southern part of the range of Lamentation Mountain). This picturesque peak is shown in Plate XXIII. Plate XXIV is a map of the middle part of the Connecticut Triassic area, showing the

PLATE XXIII.

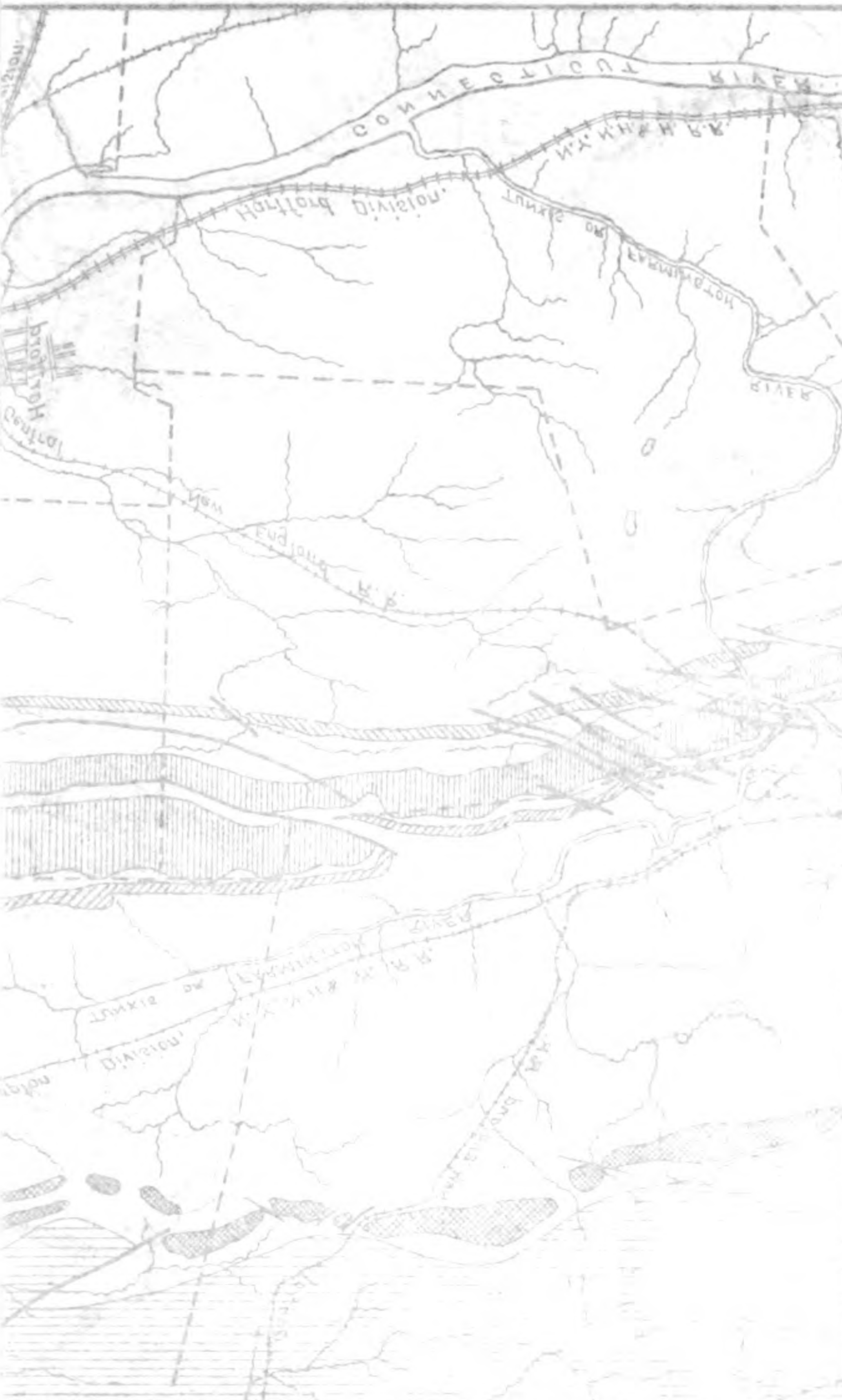
CHAUNCEY PEAK, MERIDEN.

The abrupt cliff at the right is due to the Lamentation-Higby fault.
Photograph taken under direction of W. M. Davis for U. S. Geological Survey.



MAP SHOWING TRAP SHEETS AND FAULTS IN CENTRAL PART OF TRIASSIC AREA OF CONNECTICUT.

From map by W. M. Davis in *Eighteenth Annual Report of U. S. Geological Survey.* (Slightly altered.)


CONNECTICUT RIVER
N.Y.N.H.&H.R.R.
Hartford Division
Tunxis or Farmington
River
Central
New England R.R.
Tunxis or Farmington River
Division
N.Y.N.H.&H.R.R.

principal faults; and, though no contour lines are given on the map, the reader, remembering that the main trap sheet is the ridge-making member of the formation, can see how beautifully the topography interprets itself on the hypothesis of a great series of faults.

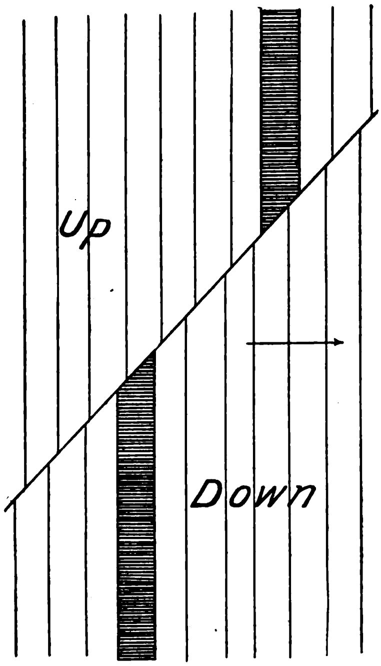


Fig. 14. Plan of Strata with oblique Fault and with the dip side going down. In this case the parallel ridges developed along the outcrops of a resistant stratum will show a negative overlap.

It may be remarked incidentally that the faults which have broken the continuity of the main trap ridge have had an important influence in the commercial and industrial life of the state, by making practicable railroad routes from the eastern to the western side of the Lowland. The fault which lies between the Hanging Hills and Lamentation Mountain permits the passage of the Hartford Division of the New

York, New Haven, and Hartford Railroad between Berlin and Meriden; the fault between Lamentation Mountain and Higby permits the passage of the Meriden Branch between Middletown and Meriden; and a little fault which dislocates Saltonstall Mountain allows the passage of the Shore Line Division between East Haven and Branford.

It is easy to determine the location of the faults very accurately where they cross the outcrops of the trap sheets, and particularly where they cross the outcrops of the main sheet. That massive sheet of trap is everywhere a conspicuous feature in the topography, and it has an individuality which is readily recognizable. In the sandstones, the location, with any degree of definiteness, of faults which cannot be directly observed, is practicable only in those places where abnormal dips indicate the drag of a fault. The sandstones and shales oppose in general but a weak resistance to erosion, and have therefore been degraded in most places towards the condition of a peneplain, which is for the most part covered by drift and vegetation. Even where outcrops of the sandstones and shales are to be found, they generally have not sufficient individuality to be recognized as belonging to any particular horizon within the formation. In the monotonous variety of beds, some coarser, some finer, some redder, some grayer, there are none that have any recognizable individuality excepting the thin strata of limestone and black shale; and those beds are so weak that their outcrops are very scanty indeed. Presumably many of the faults that have been recognized in the Triassic formation extend beyond the limits of the Triassic into the crystalline rocks on one or both sides of the Connecticut Valley; but the recognition of faults in the crystallines is difficult and uncertain on account of the extreme complexity of structure of the crystalline rocks. The plotting of faults on the map, Plate XXIV, is therefore inevitably to a considerable extent hypothetical. It should also be noted that, where a fault line on the map comes to an end, the meaning, in general, is not that we have proof that the fault comes to an end at that particular

locality, but only that our knowledge of it comes to an end.

Direction of Faults.— South of Hartford the prevailing direction of the faults is northeast and southwest. In the latitude of Hartford, the direction of the faults becomes nearly north and south, and still farther north the faults show predominantly a northwest and southeast trend, Throughout the area, at least the Connecticut portion thereof, the upthrow is on the east side in a very large majority of cases.* Among the most interesting faults are the two large ones which lie, respectively, between the Hanging Hills and Lamentation, and between Lamentation and Higby. With a considerable degree of probability these two faults can be traced across the entire breadth of the Lowland. Dislocations of the intrusive sheet on the west margin of the area, and dislocations of dikes in Cheshire and Wallingford, lie nearly in the line of these faults, produced southwestward; and two considerable portions of the eastern boundary of the Triassic area lie nearly in the line of the continuation of these faults at the northeast. Between the Hanging Hills and Lamentation, Davis estimates the upthrow on the southeast as not less than 2,000 feet, and between Lamentation and Higby as not less than 1,300 feet. Talcott Mountain is situated just in the latitude where the northeast and southwest trend changes, through north and south, to northwest and southeast. The peculiar double-ridged form of Talcott Mountain is due to the fact that for a considerable distance the trend of a fault plane is nearly parallel to that of the strike of the strata and the consequent trend of the range.

In the vicinity of a great fault it is often the case that a number of little faults may be observed. Sometimes there will be a series of step faults parallel with the main fault; and, again, the slices into which the rock is broken by such a series of parallel faults may be still further dislocated by

* In the region of Mount Tom, Emerson notes a series of faults with upthrow on the west side. *Geology of Old Hampshire County*, p. 449.

cross faults. In the vicinity of East Berlin the great fault that lies between the Hanging Hills and Lamentation appears to be broken into parallel faults, while the structure is further complicated by a number of little cross faults. The structure of this interesting locality is shown in the sketch map, Fig. 15. In this case it is obvious that the faults

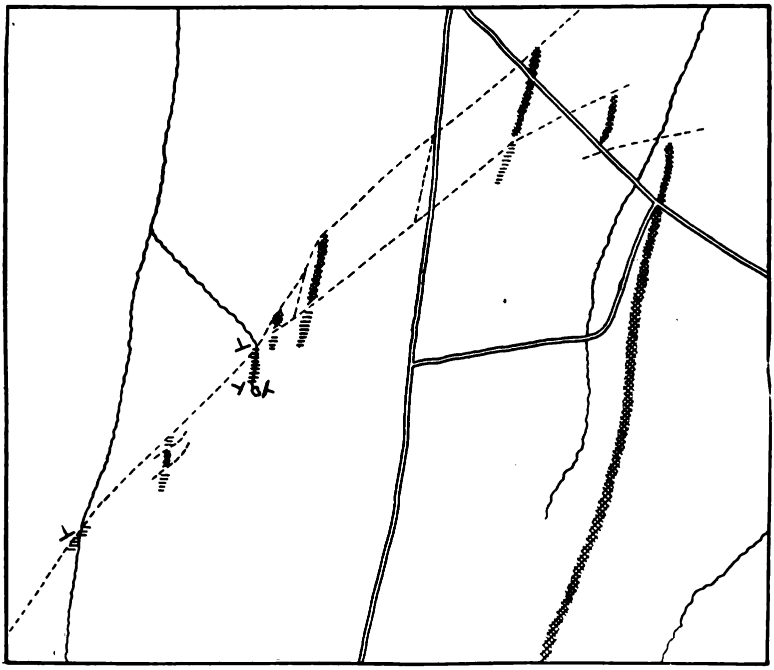


Fig. 15. Sketch map showing Faults near East Berlin. Scale, 1200 feet to the inch. Outcrops of shale and sandstone shown by horizontal lines, outcrops of trap by oblique cross lines. Faults shown by dotted lines. Dip and strike shown by the sign T.

can be definitely located only at a few points where trap and sandstone are found almost or quite contiguous along the line of strike, or where trap outcrops end abruptly, or where the sandstones present abnormal dips. The tracing of the fault lines at a distance from these critical points must be, of course, merely hypothetical. The cutting on the Meriden Branch of the New York, New Haven, and Hartford Railroad just west of Westfield station shows three

Fig. 16. Faults with Drag Dips, north wall of railway cutting, Westfield. Scale 44 feet to the inch. At the west end the stratified rocks are overlain by trap.

faults of unknown, but probably inconsiderable, throw, clearly marked in the section exposed in the wall of the cutting by the discontinuity of the strata and by steep northwesterly dips (drag dips), while the proximity of the great fault between Lamentation and Higby is indicated by the slight northwesterly dip of the whole section (see Fig. 16). There is good reason to believe that the faults which actually exist in the rocks are much more numerous than those which have been detected and of which the principal ones are shown on the map. In Professor Hobbs' work on the Pomperaug Valley, the numerous faults by which the traps of that little region are dislocated are traced most minutely and with consummate skill.

Marginal Faults.— There is strong reason to believe that the present eastern border of the Triassic area of Connecticut is due almost entirely to a series of faults. This belief is founded on a variety of evidences. From New Haven to Durham the eastern boundary of the Triassic formation crosses the synclines of Saltonstall Mountain and Totoket Mountain, the anticline between them, and the minor anticline in the middle of the Totoket syncline. If the surface of contact between the crystallines and the sandstones were the surface of the crystallines upon which the sandstones had been deposited — a surface which must be supposed to have sloped gently westward,— then the effect of a crumpling of the rocks into alternating anticlines and synclines must have been to make the line of intersection between the contact surface and the nearly horizontal plane of erosion strongly sinuous. The boundary would have been thrown into

curves convex towards the sandstones on the anticlines and convex towards the crystallines on the synclines. In fact, however, the boundary is not far from a straight line; and the slight curves which it shows are not in accordance with the rule stated above. The only effect of the folding is that on the anticlines lower members of the Triassic series abut upon the crystallines, and on the synclines higher members. The nearly straight boundary, in fact, cuts across all members of the Triassic series, from the sandstones underlying the anterior trap sheet to the sandstones overlying the posterior sheet. This relation is only intelligible on the supposition that the actual surface of contact between the sandstones and the crystallines is not far from a vertical plane. It must be assumed, then, that the boundary from New Haven to Durham is determined by a fault with upthrow on the east. The former continuation of the Triassic eastward of this fault line was carried up above the plane of erosion, and has therefore been removed. In Glastonbury and in Vernon two sections of the eastern boundary of the formation lie nearly in the line of the two great faults which separate, respectively, the Hanging Hills from Lamentation and Lamentation from Higby. In the vicinity of the eastern boundary of the Trias, in many localities, both the sandstones and the crystallines show strong indication of disturbance. Abnormal and excessive dips are frequently observed in the sandstones. The strata are very much jointed, and oftentimes shattered by a perfect confusion of little faults. The crystallines near the boundary show in many places a peculiar brecciated structure, and the presence of much chlorite. Near the Highland Park paper mill, in Manchester, the digging of a trench revealed a fault contact between the sandstones and the crystallines, the fault plane dipping 55° to the west.* While it is obvious that the evidence is not equally conclusive for all parts of the boundary, there is, on the whole, strong reason to believe that the eastern boundary is formed in the main by a series of faults. In parts of the

* Davis and Griswold, in *Bull. Geological Society of America*, vol. V, p. 526.

western boundary there are irregularities which can only be interpreted as the result of faults. In a few cases it seems probable that faults by which the trap ridges are dislocated find their continuation in small sections of the western border. In the main, however, the western boundary is remarkably straight, and there is nothing in its character that requires the assumption of a marginal fault, though it is possible that the western boundary, like the eastern, may be mainly determined by fault lines. The relations of the sandstones and crystallines at the old copper mine near Bristol, as described by B. Silliman, Jr., and J. D. Whitney,* require the assumption of a fault with upthrow on the west. Those geologists who believe that the Triassic formation extended originally much beyond its present limits, are disposed to consider the Connecticut Valley as a *graben* — i. e., a region which has slipped down between two faults. While there is nothing in the phenomena observable in most parts of the western border which requires the supposition of a fault with upthrow on the west, there is nothing which positively excludes that hypothesis. As we have already seen, a very large majority of the faults which can be proved to exist in the Connecticut Valley area have their upthrow on the east. There are, however, some exceptional cases in which the upthrow is on the west.

Professor Hobbs has shown good reason for believing that the Pomperaug Valley basin is essentially a graben, and that that little remnant of the Triassic owes its preservation to having dropped down between its bounding faults below the plane of erosion. There is more or less evidence that the other Triassic areas of eastern North America have their limits determined wholly or partially by marginal faults.†

Thickness of the Triassic Strata.— The proof of the existence of numerous faults with upthrow to the east relieves us, as we have already seen,‡ of the necessity of assuming

* *Am. Journal of Science*, series 2, vol. XX, p. 361.

† Hobbs, *Former Extent of the Newark System*, in *Bull. Geological Society of America*, vol. XIII, p. 142.

‡ Page 201.

an enormous thickness for the Triassic strata. On the other hand, the probability that numerous faults exist which are entirely undetected, or the amount of whose throw is unknown, renders it impossible to determine with any accuracy the correction which must be applied to make the trigonometric computation of the thickness of the strata yield a just result. It seems probable, however, after all allowances are made, that the formation is of great thickness. Among other indications pointing in this direction may be mentioned the great depth of some of the wells which have been bored in the sandstones without reaching the underlying crystallines. The depths of a few of the deepest of these are as follows:— Hartford, 1,250 feet; Forestville, 2,000 feet; Northampton, 3,700 feet; New Haven, 4,000 feet.* The aggregate of Davis' estimates of the probable thickness of the various members of the formation is from two to two and one-half miles.†

Dynamic Theory of the Structure.— Can we give a dynamic interpretation of the present attitude of the Triassic formation — its general monoclinal position, and its numerous dislocations? It must frankly be confessed that our knowledge of the dynamics of earth movements is too meager to justify dogmatic statements. But it seems legitimate to venture tentatively a little way in the direction of dynamic explanation.

It is a noteworthy fact that the monoclinal structure which is observed in the Connecticut Valley prevails also in the other Triassic areas. But in the Acadian, New York-Virginia, Richmond, Danville, and Dan River areas the prevailing dip is to the northwest, while in the Connecticut Valley, Deep River, and Wadesboro areas the prevailing dip is southeast. If a somewhat sinuous line is drawn from Massachusetts to North Carolina between the areas of northwest dip and the areas of southeast dip, as shown in Plate XV, that line will, in a general way, be parallel to the trend of the mountain ranges which mark the eastern border of the American continent. It is reasonable

* Gregory, *Farmington Folio*, U. S. G. S.

† *Eighteenth Ann. Rep. U. S. Geological Survey*, vol. II, p. 28.

to suppose that the northwest and southeast dips on opposite sides of this axial line find a unitary interpretation in the conception of a broad and gentle upfolding of the crust of the globe. Such a broad and gentle upfolding, involving the crust of the globe down to an unknown depth, has been called by Dana a geanticline, in distinction from those more narrowly local and often much steeper folds of particular groups of strata which are called anticlines.* The cause of such a geanticlinal movement is most probably to be sought in the cooling and consequent contraction of the interior of the globe, producing tangential strains in the crust, to which from time to time the crust yields in great wrinkles. Where such a geanticlinal movement produces a permanent elevation, the mountain range thus formed has been called by Dana an *anticlinorium*.† The most fundamental conception then, of the crustal movement which produced the monoclinal arrangement of the strata in these Triassic basins is that a broad zone of the eastern border of the continent was elevated by tangential pressure into a great geanticline. But apparently such a geanticlinal movement is apt to be associated with faulting. The broad, flat arches are apt to crack, and the blocks into which the arches are broken to slip past each other in obedience to gravitation until they find themselves in stable adjustment. In this view the differential movement of the blocks in faulting must be attributed to gravitation. Some parts of the broken arch sunk lower than other parts. There is probably no such thing as the vertical upheaval of large areas of the crust of the globe. The only force acting on a large scale in a vertical direction is gravitation, and that acts always downward. In the broad view, then, of the dynamics of the crustal movements evidenced by the structure of the Triassic for-

* The recognition of such a geanticline is of course entirely independent of the question whether the Triassic formation ever extended across the axis or not.

† *Am. Journal of Science*, series 3, vol. V, p. 432. The word anticlinorium has been used by some recent writers in a different sense. (See *Am. Journal of Science*, series 4, vol. II, p. 168; *Science*, vol. XXIII, p. 286.) The more characteristic type of mountain-making movement is the formation of a downfold of the earth's crust (geosyncline), the accumulation of a vast thickness of strata in the trough, the weakening of the lower strata of the trough by internal heat, and the final crushing of the rocks into a series of anticlines and synclines. Orogenic movements of this type occurred in eastern North America in post-Archæan, post-Ordovician, and post-Carboniferous time. (See p. 23.)

mation, we must attribute the formation of the great geanticlinal arch to tangential pressure in the crust, probably arising from the cooling of the globe, while the differential movement of the blocks into which that arch was broken along the fault planes must be attributed to gravitational readjustment. It is evident that, if the faulting was due to gravitational readjustment of the blocks into which a geanticline was broken, the natural expectation would be that on the southeastern side of the geanticlinal axis the great majority of the faults would have their upthrow to the southeast. The greatest sinking in such gravitational readjustment would naturally be near the axis of the geanticline. It will be recognized that this corresponds well with the facts which have been observed in regard to faults in the Connecticut Valley. It is an interesting fact that in the Triassic of New Jersey, which lies on the northwest side of the supposed geanticlinal axis, the great majority of the faults have their upthrow on the west side.* The relations in Connecticut and in New Jersey are thus mutually complementary.

In the introductory chapter of this paper,† in the endeavor to picture the condition of Connecticut at the close of the Triassic, a comparison was made with the Great Basin of North America. There, at the present time, we have a topography whose features are chiefly determined by faults. A series of approximately parallel mountain ranges present on one side a steep face, which is determined by a fault plane, while there is a gentle slope on the other side. That obviously must have been the topography of the Connecticut Lowland after the post-Triassic uplift, and before the work of denudation in the later Mesozoic had reduced the region to a peneplain. In all probability the resemblance between the post-Triassic conditions in Connecticut and the present conditions in the Great Basin is not only phenomenal, but also dynamical. It is the most plausible interpretation of the structure of that region that the

* Kümmel, *in Ann. Rep. State Geologist N. J.*, 1897, pp. 105-136.

† Page 26.

whole area between the Sierra Nevada on the west and the Wasatch on the east was bent by tangential pressure into a broad geanticlinal arch, while, *pari passu* with the elevation, went on the fracturing of the rising arch and the gravitational readjustment of the blocks into which it was broken.

DRAINAGE.

It is an interesting question to what extent the present drainage system of the Connecticut Valley area finds its causes in the post-Triassic deformation which we have been studying.* The question is, however, one to which it is impossible to give a very definite answer. As has been already stated, in late Mesozoic time, substantially the whole area of Connecticut was reduced to a peneplain. It is possible and not improbable, though by no means certain, that the Cretaceous sediments which now exist on Long Island once extended northward to an unknown extent over southern Connecticut. No remnants, indeed, of Cretaceous strata have been found in Connecticut, but the amount of erosion which has certainly taken place is so great that the supposition of the complete removal of the Cretaceous formation is by no means incredible. How far the courses of Connecticut rivers may have been taken upon the surface of Cretaceous strata, and may now be superimposed upon the underlying Triassic sandstones and crystalline rocks, is entirely unknown.

The Tertiary uplift, which may be said to have initiated the development of the present topography of Connecticut,† seems to have been, like the post-Triassic uplift, a geanticlinal movement. It was apparently a broader geanticline, and its axis must have lain farther west. This movement, as we have seen, gave to the surface of Connecticut a decided slope from northwest to southwest. As the general direction of slope in this region due to the Tertiary uplift was about the same as that due to the post-Triassic uplift, the stream courses which appear to be consequent on

* See Davis, in *Eighteenth Ann. Rep. U. S. Geological Survey*, vol. II, pp. 144-184; Kümmel, *Some Rivers of Connecticut*, in *Journal of Geology*, vol. I, pp. 371-393.

† See page 29.

such a slope may date from either of these epochs. If they date from the earlier (post-Triassic) uplift, they must have persisted through the long cycle of late-Mesozoic erosion.

It seems, on the whole, probable that the course of the lower Connecticut across the eastern crystallines from Middletown to Saybrook was consequent upon the post-Triassic uplift. A river so large as the Connecticut would be very likely to maintain its course through a long series of geological changes.

Consequent also upon the post-Triassic uplift may have been the considerable river which doubtless once flowed through the gap in the trap range between Plainville and New Britain (Cook's Gap), and which must have received as tributaries the Farmington and the Pequabuck, or their earlier representatives. This gap has no relation to any known faults, and must have been the result of the erosive action of a river of considerable size. If the river which flowed through Cook's gap was consequent, as is possible, upon the post-Triassic uplift, it must have maintained its course through the late-Mesozoic cycle of denudation and until some time after the Tertiary uplift. The present gap in the trap ridge, we may be sure, was cut in Tertiary time, for a gorge carved in any earlier period would have been for the most part obliterated when the whole country was reduced to a peneplain. In the Tertiary cycle of erosion, a southward-flowing stream in the sandstones would have the advantage of an eastward-flowing stream, which had to carve a gorge across the trap sheet; and some time in the course of that cycle the waters of the stream which had flowed through Cook's Gap were diverted southward, west of the trap range, and probably found their way to New Haven along the present course of Mill River.

It is possible also that the post-Triassic uplift may have initiated the river that flowed across the trap range at Tariffville, and carved the gentle outer slopes of the valley within which in later time has been carved the narrow, steep-walled gorge through which flows the Farmington. In this case, as in the former one, if the river crossing the

trap sheet at Tariffville was initiated by the post-Triassic uplift, it must have held its course until after the Tertiary uplift. That river was certainly not the Farmington as it is to-day, but it may well have been a stream which received the waters of what are now the northern tributaries of the Farmington. Like the stream which flowed through Cook's Gap, the stream which crossed the trap range at Tariffville was diverted to the south in the course of the Tertiary cycle of erosion, and for the same reason. The Tariffville stream was in all probability a smaller one than that at Cook's Gap, and had not carved its valley to so low a level when it was diverted southward. In the later part of the Tertiary cycle of erosion there must have been a single river running in an approximately straight course from Granby to New Haven, including the northern tributaries of the Farmington, the middle part of the Farmington, a small section of the Pequabuck, the upper part of the Quinnipiac, and substantially the whole of Mill River. The dismemberment of this river, and the establishment of the present drainage system of the region, were undoubtedly due to events connected with the Glacial period — to deposits of drift, and possibly to slight differential movements of the earth's crust. It is undoubtedly these events which resulted in the reversal of the course of the middle Farmington and the lower Pequabuck, sent the Farmington through the old Tariffville valley across the trap range, caused the Farmington to cut the narrow inner gorge at Tariffville (whose aspect of extreme youth proclaims unmistakably its post-Glacial date), and diverted what had been the northern part of Mill River into the Quinnipiac, which cut a narrow (post-Glacial) gorge through the sandstone ridge in Meriden.*

Unlike the stream that flowed through Cook's Gap, the stream that, at the time of the post-Triassic uplift, took its course across the trap at Tariffville, probably had its location determined by a fault. At present, indeed, as shown on

* For fuller discussion of the effects of Quaternary events upon the drainage of the Farmington-Quinnipiac Valley, see page 251 and Figs. 20-22.

the map, Plate XXIV, the Farmington River cuts across the southern extremity of the section of the main trap sheet northeast of the fault. But, as shown by Kümmel,* the river probably flowed originally directly through the break in the line of outcrop of the main trap sheet at the fault. In the progressive degradation of the country the outcrops of all members of the formation — strata and trap sheets alike — would be shifted eastward. As a result of that shifting, the outcrop of the trap sheet northeast of the fault would extend farther southward than before, as shown in Fig. 17.

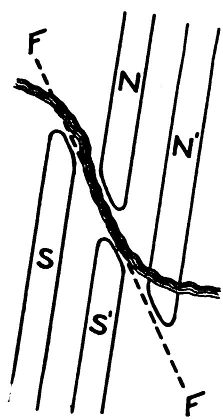


Fig. 17. Relations of Trap Sheet, Fault, and River at Tariffville. *F*, *F*, fault; *N*, *S*, trap outcrops north and south of fault before degradation; *N'*, *S'*, same after degradation.

In that way it came to pass that the course of the river crossed the outcrop of the main trap sheet northeast of the fault.

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* *Journal of Geology*, vol. I, p. 386.

Chapter IV

Glacial Geology

By

HERBERT ERNEST GREGORY

GLACIAL GEOLOGY.

THE PROBLEM STATED.

The general topography of the northeastern part of the United States is quite unlike that of many portions of the earth's surface. There is a notable absence of rough and ragged contours, sharp crests, and projecting needles. The hills are rounded off and exhibit mammiform outlines. This is true not only of the higher and more prominent ridges, but also of the lower lands, where the surface presents a billowy appearance. In other parts of the country rocks of different types and different structure assume characteristic outlines — sinks and knobs in limestone, pyramids and mesas in horizontal strata, long even ridges in folded strata, etc.; rock structure and attitude being revealed in the surface configuration. In Connecticut and adjoining states, however, the rocks are rounded and smooth, regardless of their character, and at a distance it is scarcely possible to distinguish a hill of gneiss from one of trap or of limestone. Not only consolidated rock, but sands, gravels, and loose materials of various sorts are built into hills and ridges with undulating profiles.

Another feature which attracts the attention of one coming from the west or the south is the unusual abundance of bowlders of all sizes and shapes and materials, which are strewn widely over highland and lowland alike, as well as built into walls along the roadways.

Characteristic, also, of the scenery of this region, is the presence of numerous lakes and ponds picturesquely located on hills, in valleys, in woodland, and in field. The presence of numerous bodies of water of this kind would be a topographic feature unknown in many parts of the world. The Century Atlas shows no lakes in Delaware, Maryland, West Virginia, Kentucky, Tennessee, Alabama, or Kansas; they

are likewise very rare in many other states. In the same atlas, however, Connecticut is credited with 216 lakes large enough to be represented on the map, while the United States Topographic Atlas shows 1,026 lakes and 420 swamps within the borders of this one state.

If the soil of Connecticut be compared with that of some other sections of the United States it is seen to possess two chief characteristics: namely, remarkable variety within small areas, and lack of correspondence between the soil cover and the rock beneath. Here sandstone soil may cover granite ledges, and soil made of lava fragments may lie upon shales. In the South, limestone is covered with limestone soil, and decomposed shale is the cover of shale rocks.

Since rounded hills, abundant bowlders, numerous lakes, and soil unlike the rock beneath, are not universal phenomena, but are characteristic features of the surface of Connecticut, they clearly require some explanation not applicable to all parts of the earth.

Weathering and Decay of Rocks.— One naturally looks to the atmosphere as the cause of the decomposition of surface rocks and of the formation of soil and bowlders, as the source of the water in lakes and streams, and as the chief agent in molding the earth's topography. The atmosphere is by far the most important of geological agencies producing these results. It does not operate with great rapidity, but is everywhere present and has been at work ever since the rocks have existed at the earth's surface. The work of the atmosphere is expressed by the general term *weathering*, and the character of its results is seen when we compare blocks recently taken from the Portland quarries, with stones taken from the same place a hundred years ago and used as monuments in Connecticut cemeteries. The stone from the quarry is fresh; the tombstone has a dulled surface, and even its inscription may have been eaten away; that is, the rock has weathered. This action of the atmosphere on rock at the earth's surface varies with the character of the material. If the rock contains

such constituents as can readily be decomposed chemically by the gases of the atmosphere, it disintegrates rapidly. If it contains constituents which are more resistant, it crumbles slowly. In either case, however, it decomposes. If the rocks of the earth consisted wholly of extremely resistant material, *e. g.*, platinum, the atmosphere as now constituted would be practically powerless, and the land forms produced by the earth's cooling would be permanent as they now are on the moon. If, on the other hand, rocks were composed of less resistant materials, weathering would proceed at a more rapid rate, and the lands would be reduced to plains in a much shorter time. On our particular planet the relation between the action of the atmosphere and the resistance of the rock is such that *all rocks decay*.

If a rock belongs to the igneous class, like Connecticut granites or traps, decomposition takes place by means of selecting out certain minerals which yield more readily than others to the action of the atmosphere. For instance, granite, being composed of feldspar, quartz, and mica, has a vulnerable spot in the feldspar; and this is the point toward which the water from the atmosphere, carrying carbon dioxide and taking up humus acids from the soil, directs its attack. The feldspar is decomposed into clay, and the quartz and mica remain as loosened mineral fragments to represent the original solid rock. In the case of Connecticut sandstone, which is made up of grains of sand cemented by clay, iron oxide, or calcium carbonate, the cement is removed by atmospheric agencies, and the sandstone becomes once more a sand.

In this way solid rock is loosened and made more porous, and is rotted or decomposed down to a certain depth below the surface, the depth depending upon the character of the rock and the activity of the decomposing agents. A quarry in rock decomposed by the atmosphere shows a section from the surface to the bottom of the pit, in which the rock increases in solidity with the depth, and ranges from a loose-textured soil at the surface to firm, fresh building stone below. This variation in the section is due to the

fact that the work of the atmosphere is most effective at the surface and proceeds much more slowly and with less power as the depth increases. By this atmospheric action a loosened cover or mantle or sheet of rock waste is formed on the surface of the earth. It is not allowed to remain there indefinitely, but is being continually carried away. The result of unequal decomposition of different rocks and of variation in the rate of removal of the waste is that irregularities of surface, large and small, are found everywhere. The minor inequalities are concealed from view by the cover of decomposed rock, while the larger ones are shown in the hills, the valleys, and the plains.

The Soil of Connecticut.— Soil or rock cover of the nature just described is the ordinary surface mantle of the earth, but is not characteristic of New England. In fact, anywhere in Connecticut it would be difficult to find a section which showed for a considerable extent the gradual transition from rotted, loose rock above, to firm, fresh rock below. In the southern states the soil is formed out of the rock upon which it rests, and the transition from rotten to fresh rock is commonly seen in wells, quarries, and railroad cuts. In certain parts of the south the rotten rock extends down to a depth of ten, twenty, or even fifty feet, while in the tropics it reaches still greater depths. In Connecticut there is no gradual transition from soil to rock surface, but a layer of decomposed material rests directly upon firm, unchanged bed rock. The illustrations (Plate XXV) show these relations of soil to rock. That from the District of Columbia, shown in Fig. 1, represents the normal condition — a gradual increase in solidity with depth. The Connecticut view (Fig. 2) shows the abrupt change due to peculiar conditions. Generally, on the hills the soil is hard-pan: that is, a jumbled mass of bowlders, sand, and clay; in the valleys it is more apt to be sand and gravel in layers; but in either case the transition to rock below is abrupt. The character of the soil in Connecticut and its relation to the underlying ledge cannot, therefore, be a result of atmospheric action.

PLATE XXV.

FIG. 1. FORMATION OF SOIL IN A NON-GLACIATED REGION; WASHINGTON, DISTRICT OF COLUMBIA.

Transition is shown from soil to solid rock.
Photograph by G. P. Merrill.

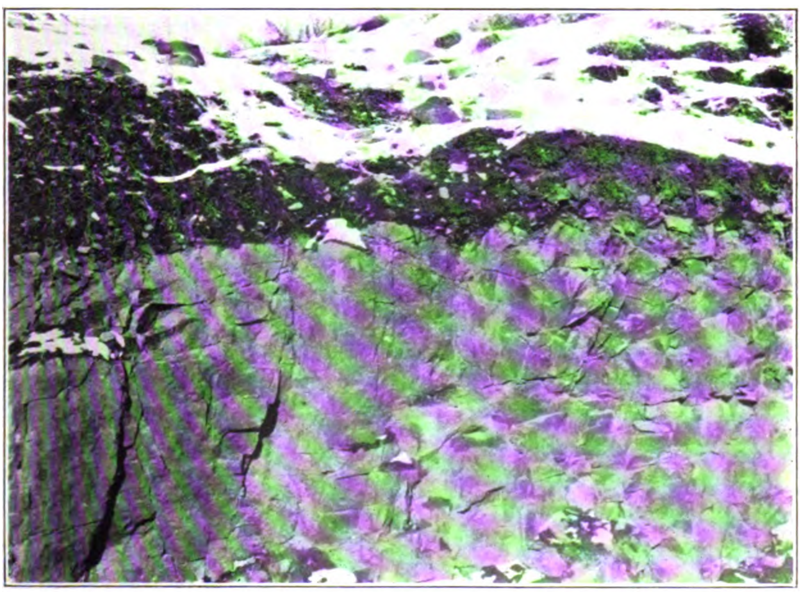

FIG. 2. SOIL IN A GLACIATED REGION; ORANGE, CONNECTICUT.

Glacial soil rests directly upon solid rock.

PLATE XXVI.

FIG. 1. HILLTOP IN NON-GLACIATED REGION; PEAKS OF OTTER, VIRGINIA.
Photograph presented by Sidney M. Loyd.

FIG. 2. HILLTOP IN GLACIATED REGION; WEST PEAK, MERIDEN.

Bowlders.— The same may be said of the bowlders strewn broadcast over the state. They are found everywhere, not only in the valleys, but on the tops of the highest hills, oftentimes in great profusion. They are large or small, rounded or angular, and exhibit great variety in color, texture, and composition. They may be of the same rock as that which underlies them, but frequently are of widely different material, and when traced to their parent ledge are found to have been moved many miles to the southward. Bowlders may be formed by atmospheric agencies, but in such cases they possess features which unmistakably indicate their origin. Thus, they are of the same material as the unweathered rock near them, and partly formed bowlders of the same rock type still connected with the parent ledge are usually present. Such bowlders exist in great profusion at the tops of mountains and hills where the atmospheric gases and the frost are least hindered in their work. On Connecticut hill-tops, however, where the rock is exposed, it is not weathered into bowlders, but is commonly smooth and firm and fresh; if bowlders are present, they are plainly unrelated to the ledge. The difference in character between these hill-tops and those in regions where bowlders formed by rock decomposition prevail is strikingly shown in a comparison of the Peaks of Otter in Virginia with West Peak in Meriden. (See Plate XXVI.) As will appear later, West Peak was formerly covered with bowlders formed in place by weathering; but they have been removed and lost, and those which are now scattered over the surface have been brought from the region about Berlin Junction.

Lakes.—Furthermore, the atmosphere alone is not responsible for the great abundance of lakes and swamps within the state. This feature is common to a large part of the northeastern United States, but is not due to the rainfall. There is no necessary relation between the amount of rainfall and the presence of lakes. Kentucky, with no lakes, has a heavier rainfall than Connecticut, and many lakes occur in arid regions.

How, then, are we to account for the presence of lakes, and bowlders, and soil resting on unaltered bed rock, and the unusual topography to which the scenery of Connecticut is due? The evidence is conclusive that these features owe their origin to the invasion of a glacier of continental

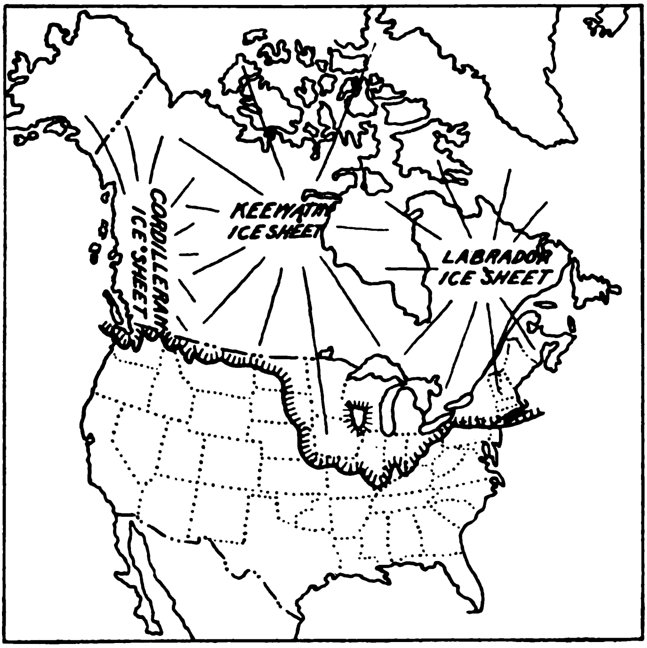

Fig. 18. Map showing Southern Limit of the North American Continental Glacier.

dimensions during the Glacial period — a glacier which occupied the area indicated on the map, Fig. 18. There is now practically unanimous agreement on this point among students of geology, but before the action of ice was thoroughly understood these features were a puzzle to layman and scientist alike.

HISTORICAL SKETCH.

In this connection it is interesting to note the various interpretations that have been given to these features of

New England, and the way in which the true explanation has been developed.

The *American Journal of Science* was established by Benjamin Silliman, at New Haven, in 1818, and is thus the oldest scientific journal in this country. An examination of its pages shows that the unusual features of Connecticut topography were recognized at a very early date. Among the greatest puzzles to the early scientists were the presence of huge bowlders on the tops of the highest hills, and the abundance of sands in ridges and plains, suggesting great water work under flood conditions. In the absence of better explanations, these were regarded as evidences of the great flood described in Genesis; and the water surging from the ocean and drowning the land was supposed to have carried these huge masses of rock and deposited the material promiscuously over the state. When the surface deposits were examined in detail, however, it was found that no such catastrophe could account for the features represented. Silliman early recognized the peculiar characteristics of our superficial deposits, as is shown by the following quotation: — "The almost universal existence of rolled pebbles, and boulders of rock, not only on the margin of the oceans, seas, lakes, and rivers; but their existence, often in enormous quantities, in situations quite removed from large waters; inland,— in high banks, imbedded in strata, or scattered, occasionally, in profusion, on the face of almost every region, and sometimes on the tops and declivities of mountains, as well as in the vallies between them; their entire difference, in many cases, from the rocks in the country where they lie — rounded masses and pebbles of primitive rocks being deposited in secondary and alluvial regions, and vice versa; these and a multitude of similar facts have ever struck us as being among the most interesting of geological occurrences, and as being very inadequately accounted for by existing theories."* At a later date Silliman published a letter signed " A," in which the following statements occur:—"There is one circumstance connected with the

* *Am. Journal of Science*, series 1, vol. III, p. 49, 1821.

PLATE XXVI.

FIG. 1. HILLTOP IN NON-GLACIATED REGION; PEAKS OF OTTER, VIRGINIA.
Photograph presented by Sidney M. Loyd.

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earth's surface, which has not, that I am aware of, been noticed by any writer on Geology. The surface of every portion of the mass of rock, composing the nucleus of the earth, and which has not been exposed to the action of the atmosphere, is found worn quite smooth, and this equally, whether the covering of earth be shallow, or deep, of whatever species of rock the mass may consist, or however unequal and irregular may be the form which it has assumed. The common appearance of the surface is highly artificial, as if worn down by some powerful but not very delicate agent. The harder parts have in some instances, especially when forming veins in a softer stratum, the *feeling* of being polished, but the general character of the surface, although smooth to the eye, is somewhat rough to the touch, with slight grooves or channels, running in a uniform direction, very nearly north and south, but from a little west of north to a little east of south."*

These passages show Professor Silliman and his correspondent to have been field geologists of exceptional ability; and their observations and descriptions have been verified time and again. They nevertheless could conceive of no other explanation of the facts than the supposition of currents of water of tremendous strength, and they suggested most fantastic hypotheses as to the cause of such currents.

In the Geology of Connecticut by J. G. Percival (published in 1842), the surface deposits are classified as Diluvium and Alluvium — the former name being applied to the materials deposited by strong currents and "accumulated loosely and irregularly," and the latter to stratified materials deposited by quiet waters.

Certain features, however, were not satisfactorily explained. No currents of water, however powerful, could lift these great bowlders and leave them scattered in such helter-skelter fashion. Furthermore, the rocks, even on the highest hills, were seen to be scratched and highly polished in a way unlike those worn by water. The theory was sub-

**Am. Journal of Science*, series 1, vol. XI, p. 100, 1826. The writer was probably Nathan Appleton.

sequently advanced that, at the time of the Noachian deluge or at some other time, icebergs had been driven through New England, and that the bowlders present had been dropped from them. It is well known that icebergs have about seven-eighths of their volume submerged, and so may reach down far enough in shallow water to polish and scratch the rocks. That ice had taken some part in the grooving and polishing of rocks, was a growing idea during the second quarter of the nineteenth century. Mr. Peter Dobson, of Vernon, Connecticut, regarded it as an important factor in producing scratches and markings on rocks, as is shown by the following extract from a letter addressed to Professor Silliman, November 21, 1825:—"I think we cannot account for these appearances, unless we call in the aid of ice along with water, and that they [the bowlders described in the letter] have been worn by being suspended and carried in ice, over rocks and earth, under water."* It is remarkable that the first published suggestion of the agency of ice in the phenomena of the drift should come from one who was not a professional geologist, but a man of business. Professor Edward Hitchcock, although strongly impressed by the views which had already been promulgated by Louis Agassiz, still declared, in 1857, "I lean, therefore, at present, to that [hypothesis] which imputes most of the work on this continent to immense icebergs, ice-floes, and shore ice."† Still more recently the iceberg theory found a champion in Sir John William Dawson, who presented elaborate arguments in its favor as late as 1868;‡ but even the influence of so great a name could not retrieve a lost cause.

With the coming of Professor Agassiz to America, in 1846, a new era was opened in the study of the surface geology of New England. Agassiz was a Swiss, and was thoroughly acquainted with the movements of glaciers in the Alps and in other parts of Europe. As far back as 1837 he

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* *Am. Journal of Science*, series 1, vol. X, p. 218.

† *Illustrations of Surface Geology*, p. 71 (*Smithsonian Contributions to Knowledge*, vol. IX).

‡ *Canadian Naturalist*, vol. III, pp. 33-44.

had announced the conclusion that the fine striæ engraven as with a diamond point on the rocks of the Jura Mountains could not have been produced by water, and that the Alpine glaciers must have extended formerly across the intervening valley. In 1840 he visited Britain, and, after demonstrating the identity of the surface phenomena in England and Switzerland, made the then startling announcement "that not only glaciers once existed in the British Islands, but that large sheets (*nappes*) of ice covered all the surface."* This was the real beginning of the study of ancient glaciation.

On coming to New England Agassiz was struck with the similarity between the deposits and the topography here and the surface features of Scotland and the Alps. Starting with this general observation, he found more and more surface forms that could be ascribed to glacial work, and finally announced his belief that the northern part of the United States had been overridden by separate glaciers or by one great ice sheet.

The glacier theory of Agassiz was advocated by Professor Dana in his presidential address before the American Association for the Advancement of Science, in 1855, and in his "Manual of Geology," the first edition of which was published in 1862. To his great influence, doubtless, the general adoption of the theory by American students of geology, in the course of the next few years, is largely due.

THE WORK OF EXISTING GLACIERS.

The proof of the theory of glaciation is found in the correspondence between the work attributed to the supposed ancient ice sheet and that known to be done by recent glaciers. The glaciers of the earth are to-day confined to high altitudes and high latitudes. A certain amount of cold is necessary for their existence; and their presence in or absence from a given locality depends upon the relation between the amount of precipitation and that of melting. As climates are now arranged, small glaciers exist about the

* *Proceedings of the Geological Society of London*, vol. III, p. 331. 1840.

high mountain groups of the world, and large ones near the poles.

If we take an individual glacier, as, for instance, one of those in the Alps or on Mt. Shasta, we find that it is an ice stream or mass of ice occupying the valley depression and reaching down somewhat below the snow-line. It is a tongue of ice, so to speak, extending a considerable distance beyond the region of perpetual snow. On top of the glaciers are commonly found masses of rock, large and small, which have fallen from the side cliffs and are carried with the ice as it moves slowly down the valley. Through the crevasses in the glacier these rocks may find their way to the bottom. If the lower end of this ice stream is examined, it will be seen that water is generally flowing from it, and that a mound or ridge or irregular mass of rock material is deposited at the end of the glacier.

In the lower course of the valley, where the ice formerly existed, and from which it has only recently retreated, it is further seen that the rock walls have been smoothed and scoured and scratched in a way very different from forms produced by water; also that masses of material are piled on the sides of the valley, and that the valley bottom is either bare, polished, and striated rock, or is covered over with a jumbled mass of bowlders, clay, etc., or is partly filled with sands and gravels left by the waters from the melting glacier. These deposits are very unlike those found in an ordinary river valley, and afford conclusive evidence that the work here is the result of a tongue of ice which has now receded farther up the valley.

When glaciers of much larger dimensions than the valley type are examined, as, for instance, the Malaspina Glacier of Alaska or the Greenland ice sheet, deposits of the same character are found, and the same effects are seen to have been produced on the underlying rock.

If, then, we find in certain parts of the world, far removed from existing glaciers, topographic forms and deposits which differ in no essential particular from those found in valleys now filled with ice streams, it is reasonable

to suppose that ice formerly occupied these places; and this hypothesis is strengthened in proportion as we find the details of erosion and deposition corresponding to details of work done by existing glaciers. Additional evidence is furnished by the fact that the other great dynamic forces — water, wind, and volcanoes — were never known to have produced results which are even approximately similar. It is on such grounds that the surface topography of Connecticut is ascribed to the work of a prehistoric ice sheet, and it will now be in order to explain somewhat in detail the effects of the work of this agency on the topography of the state.

Methods of Glacial Work.— As a geological force, ice works in a way peculiar to itself. It is not liquid enough to adjust itself to minor irregularities of the surface, but still is controlled by the larger irregularities. It is not sufficiently adjustable to erode a pit of a few feet or a few inches in diameter, as may be done by the chemical action of the atmosphere, yet it is adjustable enough to be modified by an uneven surface. The original topography of a given region is therefore effective in determining the amount of cutting into the rock below. The chief work of rivers in erosion is performed by the impact of the pebbles against the banks and bed of the stream; and up to a certain point a river is effective in its erosion in proportion to the amount of material that it carries in suspension and rolls along the bottom. Water is so mobile that it adjusts itself to all the minor inequalities in its path. Wind works by abrasion; it carries the finer particles suspended in the air and hurls them against projecting objects, but it carries only the finest of materials, and is too irregular in its direction and velocity to produce widespread uniform results.

Ice, in the form of glaciers, works in an entirely different way. The moving ice is effective in erosion because of its weight, and because of the imbedded rock fragments. In its grinding motion it is a ponderous plane, driven with practically resistless force over an uneven land surface.

The result is that it grinds down rock, both hard and soft, to a common level, and does not select the weaker or less resistant portions, as would a river or the wind. Its work is like that of a giant power-plane, which goes across knots and clear places in a board with equal effect. A mass of ice a thousand feet in thickness, such as was present over the locality of New Haven during Glacial time, exerts a pressure of 50,000 pounds per square foot. This enormous weight and the pressure which impelled it slowly forward produced the great erosion and rounding which are now so conspicuous features in the topography of Connecticut. A glacier is a coarse tool, yet at the same time a tool amply sufficient and admirably adjusted to perform all sorts of grinding and polishing.

As a transporting agent it is very unlike wind or water. Water can carry rock fragments of limited size, the weight of the largest fragments (if, for simplicity, we suppose the shape to be alike and the specific gravity equal) varying as the sixth power of the velocity. Glaciers carry large and small bowlders with equal ease. When materials are deposited by water, they fall in accordance with their size and specific gravity, and are therefore sorted and stratified; while a glacier deposits them in unassorted masses, regardless of their shape, size, or composition. In passing over a new land area the work of an ice stream would be first to scrape off all the soil that had been formed over the rock, and usually not only that, but to grind down into the rock itself to a greater or less distance. Hence, after the retreat of the ice, the soil which, under the action of the atmosphere, had been formed during long geological time, would have been removed, and that left on the ground would be entirely different in character from the rock below. This explains why the soil in Connecticut is commonly made of materials unlike those in the underlying ledges. For this reason, also, as a rule, sections in wells, cellars, and quarries in the state do not exhibit a gradual transition from surface soil through rotten rock to firmer and firmer rock, but show a clean-cut line between the cover and the bed underneath.

The soil rests directly upon fresh, unweathered surfaces, as shown in Plate XXV, Fig. 2.

The method of work of the water running from a glacier is exactly the same as that of other running water and requires no special explanation.

THE WORK OF THE GREAT GLACIER IN CONNECTICUT.

Glaciation.— The work of the ice sheet in general is included under the term glaciation, and exhibits two main phases; (1) the work done directly by the ice, and (2) that effected by water resulting from the melting of the ice. The work done directly by the ice is first of all shown in the appearance of the ledge or bed rock which has been overridden by the ice sheet. Under the influence of the atmosphere such a ledge would be covered by partially decomposed rock, and would show a dulled or weathered surface; but, when overridden by ice, the rock is worn smooth, and is scratched or polished.

Striæ.— Part of this smoothing and polishing is done by the ice itself because of its great weight and movement, but a much larger share is done by the bowlders and pebbles that are imbedded in the bottom of the ice sheet. These are shoved along over the ledges, and cut grooves or fine lines in proportion to their size. When the pebbles are very small they result in polishing the rock. Plate XXVII shows the polished and scratched rock surface on South Mountain, in Meriden. All the soil and decomposed material have been carried to the southwest by the glacier, and only a few foreign pebbles remain. The characteristic glacial striæ may be observed in Connecticut wherever ledges are exposed which have not weathered to any great extent. Resistant rocks of fine texture, such as the traps, granites, gneisses, and quartzites, are best adapted to retain scratches; but schists, limestones, sandstones, and even shales, retain records of the ice invasion. These grooves and scratches will of course be in the direction of the main ice movement, and will enable us to determine the course of the ancient ice sheet. On the accompanying map (Fig.

PLATE XXVII.

GLACIATED SURFACE, SHOWING GROOVES AND STRIÆ; SOUTH MOUNTAIN, MERIDEN.

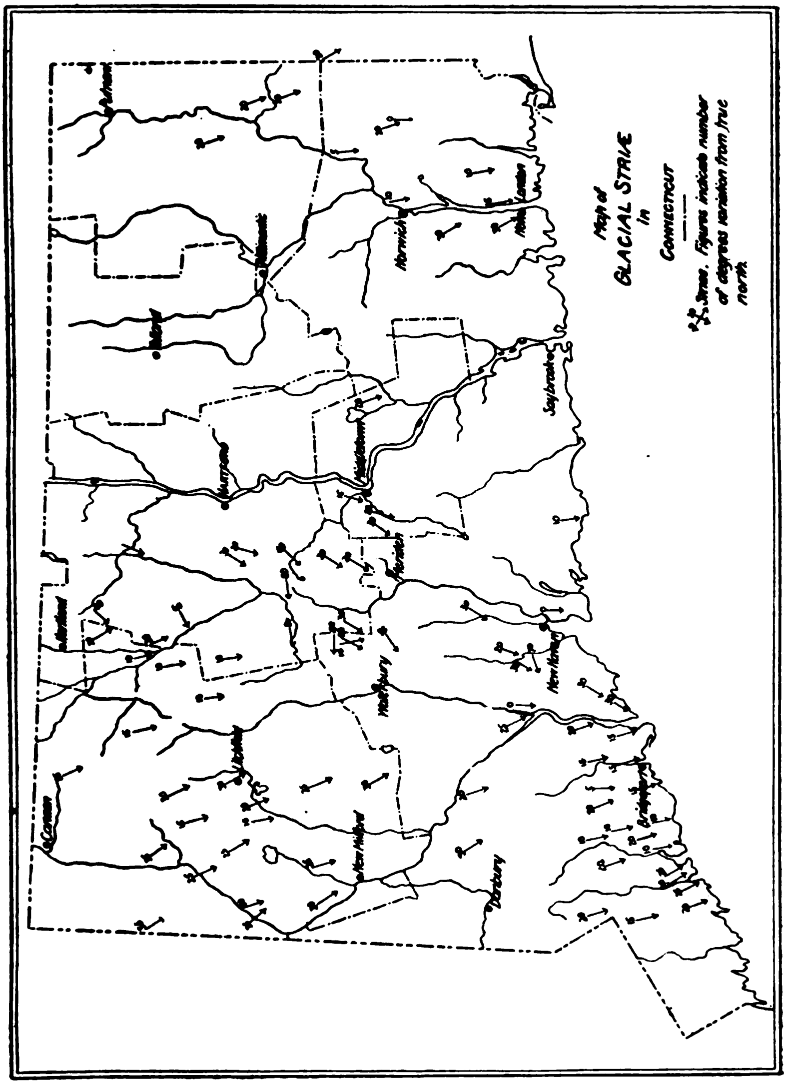
Map of
GLACIAL STRIÆ
in
CONNECTICUT
Striae. Figures indicate number of degrees variation from true north.
Putnam
Willimantic
Norwich
New London
Saybrook
Middletown
Hartford
Meriden
New Haven
Waterbury
Bridgeport
Danbury
New Milford
Canaan

Fig. 19.

19), the courses of a number of striæ are plotted, and it will be seen that the main movement of the ice over Connecticut was a little east of south, but that, where large valleys existed, the lower part of the glacier was controlled by them, and the variation in the direction of the striæ shows the changes induced by the topography.

Glacial Pebbles.— Not only are the rock ledges modified by the ice sheet, but the pebbles and bowlders held in the bottom of the ice will themselves take on characteristic forms. They are, as it were, chisels held on the lower side of a giant power-plane; while the board underneath the plane is smoothed off, the chisels are at the same time worn down. In this way the bowlders in the bottom of the ice are polished and grooved and striated along one or more faces, leaving other sides unaffected. Such pebbles are easily distinguished from pebbles worn by water, for in the later case the pebbles have been rolled against each other so that their corners and angles are entirely worn off, leaving them approximately spheroidal. Glacial pebbles are polished and flattened, but not rounded. If collections of water-worn and ice-worn pebbles are compared, these differences will at once be apparent, as shown in Plate XXVIII.

Bowlders.— Another evidence of ice work is the great abundance of bowlders strewn without order over the entire state. Many are very small; those ranging in size from six inches to three feet in diameter are abundant; many are found five to ten feet in diameter; and certain ones occur which exceed twenty feet in their largest dimensions. The moderate-sized ones have been in many places picked off from the surface and built into numerous stone walls, the smaller ones still remaining in the fields, while the largest ones constitute prominent landmarks. It is noted, furthermore, that these bowlders lie in every conceivable position — on the tops of the highest hills, in the valleys, and on the hill slopes. They may rest on very large bases, or be nicely balanced on some small facet, apparently

PLATE XXVIII.

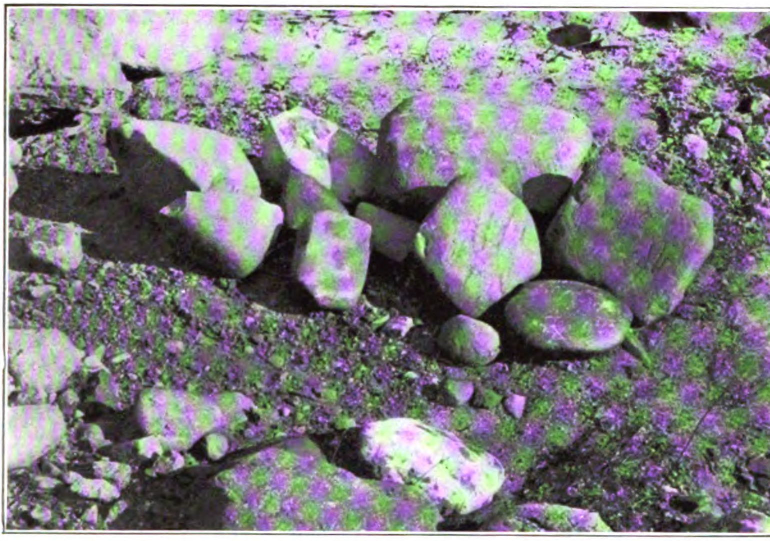

FIG. 1. GLACIATED PEBBLES — ANGULAR STONES SMOOTHED AND STRIATED
FAIR HAVEN.

FIG. 2. WATER-WORN PEBBLES — ROUNDED; FAIR HAVEN.

in an insecure position. Oftentimes the solid rock underneath is seen to be polished and grooved, and very frequently it happens that this rock is of an entirely different character from that which constitutes the bowlder. It will be readily seen that such a bowlder could not be the result of weathering of the ledge in place, but has been brought from some distance and deposited in its present position. These bowlders may often be traced back to their original ledge, and thus give evidence of the distance of transportation and the direction of ice movement. Sandstone bowlders from central Connecticut occur at Montville; dolomite bowlders from Canaan are found in Litchfield; and bowlders occur at New Haven which have traveled from the Berkshire Hills. They are far too heavy to have been carried by wind, and their weight and their shapes make it unreasonable to suppose that they could have been deposited by water. The simplest explanation to account for the character and distribution of bowlders is that they were imbedded in the ice in the interior or at the bottom of a glacier, or were riding on top of the ice sheet; and, as the ice melted, they dropped down and came to rest wherever and in whatever position they might be when released from the ice. These larger bowlders have often received local names, and have long excited interest. The Judges' Cave at New Haven is a typical specimen. Though now broken, it was originally doubtless one mass weighing about 1,000 tons, and was probably transported from some point north of Meriden.

Till.— When a glacier retreats in a mountain valley, it usually leaves at the front and at the sides masses of heaped-up deposits called moraines; in addition to these it also distributes material everywhere along the bottom of the valley. The latter material comes from the rock torn off from the glacier's bed, with the addition of fragments from the top of the ice. In general the deposit on the floor of the valley is hard packed, and contains pebbles of various sizes and in all sorts of positions, with the clay and sand made

16

from finely ground matter (see Plate XXIX, Fig. 1). All the rock débris which accumulates underneath the ice is called the ground moraine. In the case of the continental ice sheet, part of which occupied New England, the margin extended through Long Island; and the great mass of material reaching from Brooklyn eastward and forming the "back-bone" of the island, is a terminal moraine, indicating the position of extreme advance of this gigantic glacier. Throughout the state of Connecticut the ground moraine was deposited; and, because of its method of deposition, the material composing it is a compacted mass of unassorted and unstratified bowlders, pebbles, and clay, which have been pressed down by the great weight of the ice above. This deposit is the *till,* or "hard-pan," as it is popularly called. Its bowlders are those which are met with in fields, and which are uncovered in sinking wells, particularly on the higher lands. The hard-pan, or till, is deposited very generally over the state, and has been jammed against the hills and spread over the highlands in such a way as to reduce many minor inequalities in the land surface. From a study of the well sections in the state it is seen that the till varies in thickness from a few inches where the topography was such as to allow even distribution, to over one hundred feet where the ice has crowded its ground moraine against some valley side.

Drumlins.— Over an even land surface an ice sheet of uniform thickness would spread the till fairly regularly; but, if for any reason the amount of ice is decreased, or the original topography is such that it is difficult for the ice to carry all the material in the ground moraine, it may pile it up in heaps and override it, just as rivers deposit sand bars along their beds when they are unable to carry all the material furnished by their tributaries. These mounds of till are called *drumlins.* They are elliptical hills, elongated in the direction of the ice movement, and in Connecticut are generally a quarter of a mile or more in length, and rise forty to one hundred feet in height above their bases. They have remarkably smooth convex outlines, quite unlike the ordi-

PLATE XXIX.

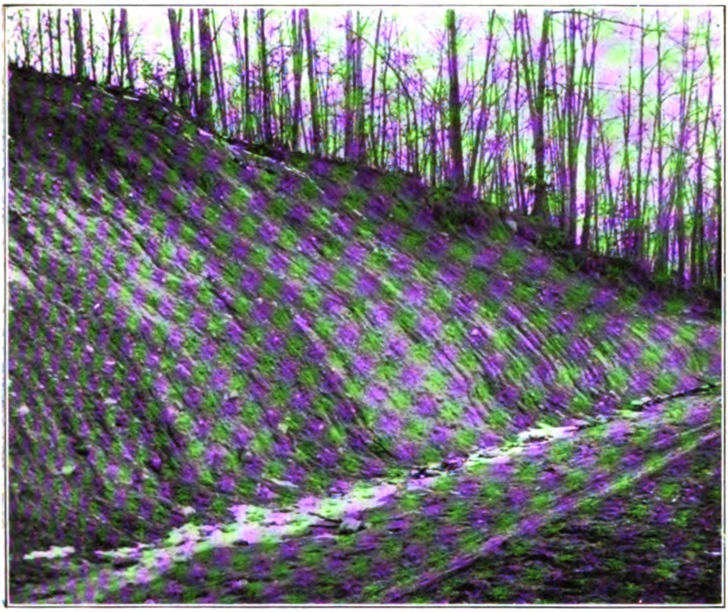

FIG. 1. TILL, NEAR YALE FIELD, NEW HAVEN.

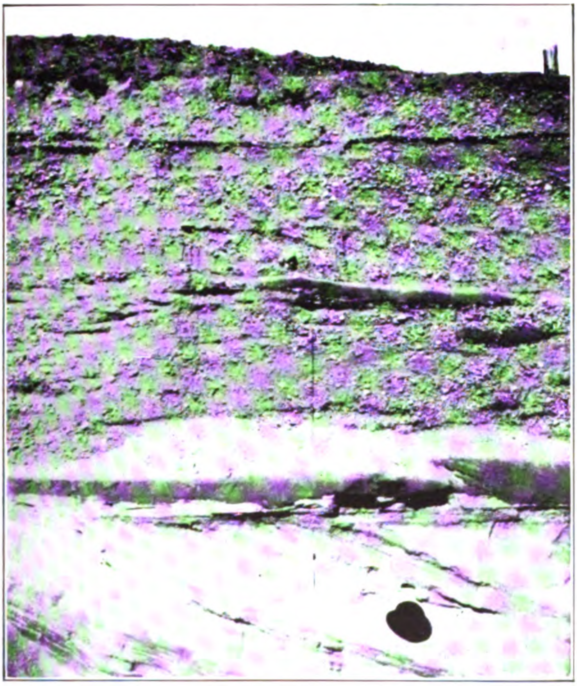

FIG. 2. STRATIFIED DRIFT NEAR YALE FIELD, NEW HAVEN.
The hat in the picture shows size of pebbles.
Photograph by Freeman Ward.

PLATE XXX.

DRUMLIN, NEAR HIGHLAND PARK, MANCHESTER.

Photograph by H. H. Robinson.

nary hummocky deposits of a moraine. When occurring in groups they constitute prominent topographic features, and rise above the general surface much like rock ridges, but with the characteristic drumlin form. The hills about Pomfret are of this character, as are also those within the city of New Britain; Buckwheat Hill in Meriden is also of this type, and many more are scattered over the state. Plate XXX shows a typical Connecticut drumlin. Rock ridges and sand deposits sometimes imitate the forms of drumlins, but close examination reveals the difference. Drumlins have no bed rock exposed, and no stratified sands or gravels enter into their composition. They are entirely of till; and this fact, together with their form, serves to distinguish them from other topographic features.

Composition of Till.— The composition of till is well shown by analyses of sixteen samples taken from drumlins by Professor Crosby.* All the stones over two inches in diameter, amounting to from 8 to 10 per cent. of the whole bulk (rarely 20 per cent.), were taken out. The finer parts remaining were analyzed mechanically, and found to have the following composition:—

Gravel	Coarse	17.08	
	Medium	2.99	24.90
	Fine	4.83	
Sand	Coarse	3.33	
	Medium	9.25	19.51
	Fine	6.93	
Rock flour	Coarse	12.80	
	Medium	6.52	43.76
	Fine	24.14	
	Superfine	0.30	
Clay	First size	0.86	
	Second size	9.13	11.77
	Third size	1.78	
			99.94

* *Proceedings of Boston Soc. Natural History*, vol. XXV, p. 123.

[The material classed as clay is a soft impalpable mass coming from the mechanical disintegration of argillaceous rocks or from the chemical decomposition of other rocks. Rock flour is mechanically formed, and is mostly fine quartz, and always feels gritty.]

Stratified Drift.— The stream which issues from the snout of a glacier is always heavily laden with pulverized rock. This material is carried for some distance, and is finally deposited where the stream, because of decreased velocity, is no longer able to carry the load. In the same way, water produced by the melting of the continental ice sheet has deposited material over all of the lower lands in Connecticut. It will be readily understood that deposits formed in this manner differ in no important particular from those made by ordinary rivers when at flood stage; the only difference being that rivers are supplied by the rainfall, and the materials borne along come from rock decomposed by the action of the atmosphere, whereas, in the case of glacial streams, the water comes from the melting of the ice, and the material carried is that previously ground up by the ice mass. Because the ordinary river carries material which was taken from the surface of the earth and which had been greatly weathered and oxidized where exposed to the atmosphere, the muddiness of rivers is yellowish in color; whereas the glacial streams, carrying freshly ground rock, are more apt to present a milky appearance. Deposits made by glacial waters consist of ground-up fragments of whatever rock was acted upon by the glacier, and accordingly show great variety in composition.

The variations in the velocity of glacial rivers resulted in the deposit of materials of different grades of fineness. When streams were at flood stage, pebbles from one inch to six or eight inches in diameter, or even larger, could be transported; in more quiet water only the finest sediment could be borne along. Therefore glacial deposits made by water are everywhere in layers, or stratified; materials of different sizes or different specific gravities form distinct beds. For this reason the general name *stratified drift* is

given to this class of deposits. Such water-laid drift may be readily distinguished from till by the fact that it is sorted and stratified, and does not contain bowlders of large size, whereas till is an unsorted, jumbled mass, variable in texture and composition, and containing fragments of all sizes up to the largest known bowlders. The contrast between the two types of deposit is shown in Plate XXIX.

Sand Plains.— When the waters from the melting ice were not confined to definite channels or valleys, they spread widely over the country, depositing the material in the form of a plain. Such plains may have been above sea level, or may have been deltas slightly below sea level. The streams wandered back and forth on these plains, varying in velocity and in quantity, but with the result that the original topography was completely buried in a fairly even stretch of sands and gravels. Such a sand plain exists in the region about Wallingford. Where bodies of quiet water were present, and streams from the melting ice entered them, the coarse material would be dropped near the shore, and only the finest particles could be held in suspension long enough to be carried far out and deposited on the bottom of the lake. When the waters drained away, such areas would form clay beds. Deposits of this nature are believed to constitute the clays of Berlin, North Haven, Milldale, and other localities in Connecticut. Plains formed by glacial streams and lakes are common features, and may cover but a few acres, or may extend over many square miles, as the plains about Plainville and Plainfield.

Kames.— Near the edge of the melting ice sheet, just in front of and under the ice, the deposition of material would be extremely irregular. The free movement of the water would be obstructed by morainal material and by the broken masses of ice, so that, instead of flowing with a regular current, it would gush out with considerable force in certain places, while it would be ponded back at other places. Blocks of ice would remain detached, partly surrounded with sand or gravel, and considerable material

would be deposited by the water underneath the ice. The resulting topographic form would be a series of mounds and short interlocking ridges with hollows, the depressions being either dry or filled with water. Such mounds and ridges are called *kames,* and indicate a temporary halt in the retreat of the ice-sheet. These kame areas are generally confined to valley districts, or to the sides of ridges where the water emerged from the ice. In the Nepaug Valley, west of Collinsville, kames are well developed (see Plate XXXI, Fig. 1); also west of Cheshire, and in Glastonbury, Avon, and many other towns.

Eskers.— Streams running underneath the ice for any great distance, and fed by the melting ice itself or by water dropping down through the crevasses in the glacier, would make for themselves definite subglacial channels. They would meander after the manner of an ordinary surface stream, and would deepen their channels or deposit material in accordance with their velocity and load of detritus. If such a subglacial stream should deposit considerable material on its valley floor, the result would be an accumulation of sand and gravel, along a sinuous line, held up by the ice on both sides. When the glacier finally melted, the sand and gravel which had been deposited would be left as a ridge, marking the course of the subglacial stream. Ridges of stratified drift formed in this manner are called *eskers,* and serve to determine the direction of subglacial drainage. They are long, winding ridges of sand and gravel, rising to a height of from ten to thirty feet or more, and are usually sharp-crested, and often as regular as an artificial embankment. Eskers would naturally not form under the main part of the ice, but rather toward the extremity of the ice sheet; and the establishment of such definite channels implies the maintenance of one position for a considerable period of time. Eskers, therefore, like kames, mark a position where the glacier made a halt in its retreat. They are well developed in Connecticut, in Hartland, in Burlington, and elsewhere. Plate XXXI, Fig. 2, shows the esker

PLATE XXXI.

FIG. 1. KAMES, NEPAUG VALLEY.

FIG 2. ESKER, EAST HARTLAND.

at East Hartland. It has a length of about a mile, and rises above the general level about thirty feet. A common feature of eskers is a swamp or lake on one side or both. Compounce Pond owes its existence to an esker which forms a ridge on the east and southeast. These long, winding ridges of sand and gravel are not confined to valley regions, but may occur on high land, and they cross the hills and valleys without regard to the present topography, in a manner that would be impossible for any surface stream.

While it is believed that eskers have been most commonly formed by subglacial streams, as described above, it is probable that some eskers owe their existence to streams flowing on top of the ice mass.

Kettle-holes.— The front of a melting ice sheet would not recede uniformly, but would present a great complexity of lobes and indentations, large and small. From time to time blocks of ice would become detached from the main mass, and might remain grounded or be floated for a time as icebergs. Such ice blocks might be entirely or partly covered with drift deposited by the streams from the melting ice. The block might remain thus partially concealed for a considerable time; but, after a while, it would melt, and the sand and gravel slump down on all sides to occupy its place, forming a conical depression. Such depressions are called *kettle-holes,* and occur usually on sand plains formerly covered by widespread streams at flood stage. They give the plain a pitted appearance. The New Haven sand plain is thus marked, particularly about Pine Rock and Mill Rock.

Lakes.— One of the characteristic features of Connecticut topography, as compared with that of the states farther south and west, for example, Tennessee or Kentucky, is the great abundance of lakes, swamps, and ponds. The Connecticut Topographic Atlas shows 1,026 lakes and 420 swamps.* There are of course many others too small to be

* In counting these lakes the larger artificial ponds are included. Most of these were originally lakes or swamps, and the dams have only increased the area of the water body. The number of basins made entirely by man is probably more than offset by the number of water bodies drained since the first settlement of Connecticut.

mapped. These lakes owe their existence chiefly to the fact that Connecticut was in the path of the continental glacier.

Lakes are temporary features of a landscape, and can exist only where the land has been recently raised from the sea or modified by some widely acting agent. Rivers tend to destroy lakes both by filling in at the upper end and by cutting down the outlet. Furthermore, vegetation works into lakes from all sides, converting them first into swamps, then into bogs, which finally become grassy plains, whose history is revealed by the thick deposits of peat beneath the surface. It is only because the surface of Connecticut has been lately modified that such an abundance of water bodies exists. When the glacier came down across New England from the north, it plowed off the loose material from hill and valley alike, cutting deeply in some places, filling up other places, thus changing extensively the details of the preexisting topography. When the glacier retreated, it left material spread irregularly over the entire district. Till and stratified drift, in the form of ground moraine, terminal moraines, kames, eskers, and sand plains, were left behind in such a manner as completely to remodel the landscape. Valleys were filled, elevations of different types were made, and in places rugged land forms were converted into plains of till or stratified drift. Rain falling on such a surface did not find stream channels already established to carry it to the sea, but found disconnected depressions of various shapes and sizes. The hollows, accordingly, were filled with water; and ponds and lakes must abound until the streams can be reestablished and a system of ramifying tributaries developed to drain the land. Sufficient time has elapsed since the Glacial age for many streams to be reestablished on the modified surface; but, while numerous lakes and ponds have been drained, hundreds of them still remain as abnormal parts of drainage systems.

Most of the lakes of Connecticut occupy depressions made by the deposition of glacial material, but some lakes

are contained in rock basins, and owe their existence to the action of ice in eroding the rock. For example, Lake Saltonstall at New Haven does not seem to be due to the obstruction of the former drainage system, but to have been eroded by the ice from shales overlying a lava flow. It is separated from the waters of Long Island Sound by only a few feet; it has an extreme depth of 108 feet, its bottom being more than 82 feet below the level of the sea, whose tides rise and fall at its very edge. The water is fresh, and is used for the New Haven water supply.

Swamps.— Lakes and swamps are to be considered as members of one family, and to differ only in age. Originally they were all lakes with no vegetation surrounding them. The material forming their shores was either rock or glacial débris. If rock, many years must have elapsed before it became sufficiently decomposed to form soil; if till or stratified drift composed the lake border, the material was already sufficiently broken up to give access to roots. In either case considerable time must have elapsed after the final retreat of the glacier before vegetation to any extent took possession of the lake shores. The first plants to appear were lichens and mosses. Certain mosses, particularly those of the genus *Sphagnum*, have a habit of growing out on the water surface and forming a mat of intertwined stems connected with the shore. At this stage the lake is an open water body with a border of vegetation floating near the rim. Gradually this rim of moss creeps toward the center of the pond until finally it is completely closed in and covered over with a layer of vegetation. The lake is now a swamp; and such a swamp, with a floating layer of aquatic plants, is known as a "quaking bog"; it is possible in some cases to walk across the old lake on a mat of vegetation while the water remains below. These mosses have a habit of growing at the top while the old stems are dying below, and the rotted fragments drop to the bottom of the pond and help to fill it up. This decayed vegetable matter is swamp muck, and may accumulate until the pond is completely filled and

becomes a bog of peat. The peat remains saturated with water for a very long time, and usually until the bog is artificially drained. Speaking in geological terms, these peat bogs are the beginnings of coal beds. As soon as the moss and similar species have made some headway over the water surface, many other forms of plants come in to take possession. Sedges, grasses, and other herbaceous plants crowd out from the shore line. Alders, willows, white cedars, and other water-loving shrubs follow. The work of vegetation is greatly aided by rain and running water, which bring down material from the higher ground and deposit it along the borders of growing swamps. When drained, these peat bogs may be converted into rich agricultural lands, and they contain at the same time a very extensive supply of peat, which is available as fuel.

Thus it is seen that there is every gradation between lakes with shores of rock or glacial drift, and swamps partly or entirely clogged by vegetation. At the close of the Glacial period there were probably 4,000 lakes within the state of Connecticut, which owed their origin to the ice invasion; 1,026 remain somewhat as originally formed; 420 are much choked with vegetation, and are represented on the map as swamps and bogs. The other 2,500 have been drained by the natural development of stream tributaries, or filled with débris from the sides, or completely conquered by aquatic plants. They now exist as plains of small extent and form choice garden spots.

Modified Drainage.—Before the advent of the ice sheet the rivers of Connecticut took a general course to the south and southeast, in accordance with the slope of the plain produced by an uplift near the close of Cretaceous time (see page 29). Some of these streams seem to have been controlled in their direction by the structure of the rocks underneath, as has been indicated by Professor Hobbs.* The presence of the ice sheet altered the surface of Connecticut to such an extent that many of the rivers no longer

* *The River System of Connecticut* (*Journal of Geology*, vol. IX, p. 469).

run in their original channels, but have taken new courses and show modifications which are not part of a stream's normal development.

When a river system has opportunity to develop on a land surface, unaffected by accidents, the tributaries slope in the same general direction as the main stream, and enter the main stream at acute angles. They do not normally run parallel with the main stream, nor in a direction opposite to that of the main stream. Furthermore, under normal conditions, the tributaries of a stream have the same slope as the main stream, or a steeper slope, and meet the main stream at grade.

If we look at a map of Connecticut, we shall find that there are many streams which do not have these normal characteristics; there are tributaries running up stream, so to speak, and tributaries which have practically no slope, and still others which meet the main stream, not at grade, but by coming over a waterfall. Many streams, moreover, have apparently been cut in two, and drain in opposite directions, although their common valley continues as before. Some stream valleys have lakes along their course, which again is an abnormal feature in stream development. To make these points clear it may be well to describe a particular river system and to show the changes which have taken place because of the presence of a great ice sheet.

The Farmington River.— The Farmington River (see Fig. 22) rises in Massachusetts to the north of Otis, and flows southeast for a distance of about thirty miles to Farmington. It there turns abruptly north to Tariffville, a distance of fourteen miles; finally bending to the east and southeast to enter the Connecticut River at Windsor. It receives many tributaries from the north, and certain large streams from the south and west. By an examination of the glacial deposits and the ancient valleys and the general structure of the region, we find that the Farmington has been very greatly modified, and that the course that it now holds is entirely abnormal. In pre-Glacial time this river

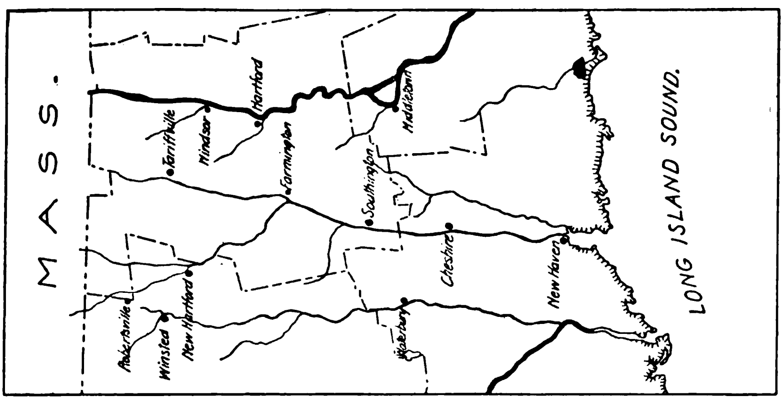

Fig. 20. Supposed Pre-Glacial Drainage of the Farmington-Quinnipiac Valley.

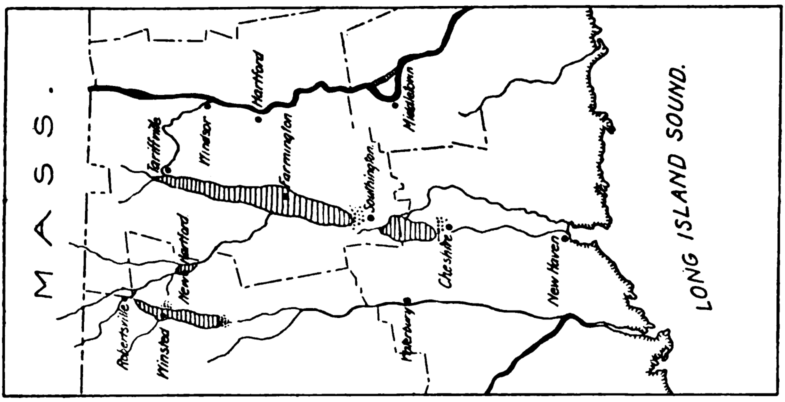

Fig. 21. Supposed Drainage of the Farmington-Quinnipiac Valley at the close of the Glacial Period.

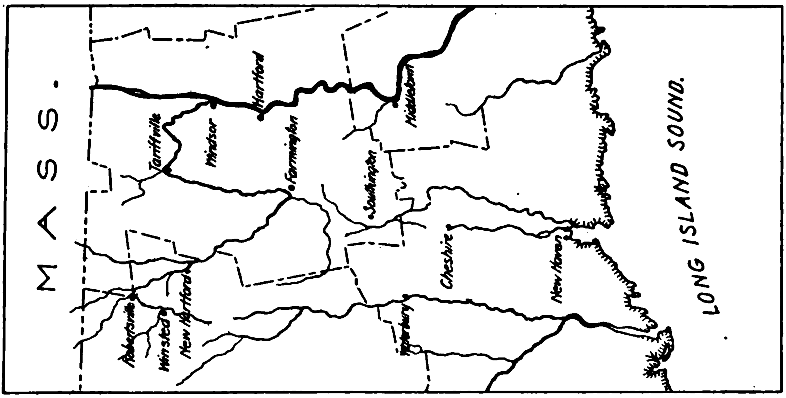

Fig. 22. Present Drainage of the Farmington-Quinnipiac Valley.

flowed from the vicinity of Congamuck Ponds directly south through Farmington, Plainville, Southington, and Cheshire, and entered the Sound at New Haven, as shown in Fig. 20.* The main tributaries from the west were the upper Farmington, which came down from Massachusetts through Colebrook, Barkhamsted, and New Hartford, and the Pequabuck, which came through Bristol. During the Glacial epoch, the entire river system was buried beneath the ice. As the ice sheet retreated, it left deposits of material at different places along the Farmington and its branches, which dammed the stream, and formed a number of lakes, interrupting the continuity of the river system (see Fig. 21). A lake was formed at Pine Meadow; the stream below that point was blocked, and found a new course for itself through the gorge at Satan's Kingdom. The pre-Glacial Farmington River was dammed at Cheshire, and was forced to give up its course to New Haven. It turned accordingly to the east, and carved the gorge of the Quinnipiac through a sandstone ridge at South Meriden. Another dam was built in the region of Southington, and a lake was formed extending through Plainville, Farmington, and Avon. The lowest place in the rim of this lake was at Tariffville, and the stream was forced to take that roundabout way to the Connecticut River. Mill River and Quinnipiac River represent portions of the pre-Glacial Farmington, and the Northampton Division of the New York, New Haven, & Hartford Railroad, which is built along the line of an old canal, runs for a large part of its course along the channel of the ancient river.

In the vicinity of Winsted the arrangement of tributaries to the upper Farmington, in Glacial and pre-Glacial times, was very different from the present. Mohawk Brook, which is now a small stream entering the Farmington near Pleasant Valley, has passed through several stages. At one time, previous to the Glacial period, Mohawk Brook and Mad River at Winsted were parts of the same stream, and drained

* For a discussion of probable drainage conditions at a still earlier period see page 220.

a considerable area from Norfolk eastward. Later the Naugatuck River worked up through Winsted, and captured the western (upper) part of this stream, so that Mad River became a tributary to the Naugatuck, and reached the Sound by way of the Housatonic. The advent of the ice sheet modified this drainage considerably; a dam was built in the Naugatuck Valley, south of Burrville, by material left by the glacier, and similar deposits in East Winsted served to close up the channel through the Mohawk to the east. These two dams formed a lake which extended over the present site of Winsted, from Robertsville to Burrville, into which Mad River drained from the west. These glacial dams were built so high that the lowest part of this newly made lake basin was at the north, and the lake overflowed into Sandy Brook, thence into the Farmington, near Riverton. The stream which wanders along the floor of the extinct lake is significantly called Still River. The falls at Robertsville date from the time of the ancient lake, and have since been cutting a gorge back from Sandy Brook toward Winsted. The changes above described, subsequent to the capture of Mad River by the Naugatuck, are shown in Figs. 21 and 22.

Still River at New Milford is another illustration of the modification of drainage by the ice sheet. This river runs north in a direction opposite to that of the Housatonic, to which it is a tributary. Many similar instances within the state might be pointed out.

Waterfalls.— If a river system is allowed to develop normally, unhindered by accidents, it continually cuts its channel deeper, until its profile from source to mouth is reduced to a smooth and gentle curve, concave upward, called a profile of equilibrium. That curve, at its lower extremity, coincides with the sea level, which is the general base-level to which rivers are working. Its tributaries likewise cut their profiles to profiles of equilibrium, the base-level of each tributary being the level of the main stream at the mouth of the tributary. When that condition is reached,

the entire river system is said to be graded, and rapids and waterfalls are practically unknown. When, however, a dam is formed in a stream, either artificially or by a glacier, waterfalls may be produced, which, as they are cut back, may be converted into rapids. The same thing happens when a valley is filled and the stream is forced to make a new way for itself across the country, until it drops again into its former channel or into the valley of another stream. Waterfalls are common in Connecticut, and practically all of them are due to the fact that the pre-Glacial drainage system has been greatly modified, and the course of rivers changed by the deposits from the ice sheet.

ECONOMIC RELATIONS OF GLACIAL DEPOSITS.

Soils.— Connecticut soils are practically all glacial. The material composing them has been carried for some distance from the north, usually but eight or ten miles from its source, but some of the material has come from Massachusetts, from Vermont, or even farther north. It is therefore *transported soil,* in contrast with the local soils in the southern states, which come from the decomposition of rock in place. Because of its origin the soil contains fragments of rock of all sorts — igneous, sedimentary, and metamorphic— and of all shapes and sizes. A great variety of soil is therefore found within a limited area, and adjoining fields may differ markedly in their agricultural value because of different soil constituents and textures.

Rocks thinly covered by till, and areas where coarse till predominates, are occupied by forests. Either they have never been cultivated or they have been abandoned. Where the bowlders are not too numerous, such areas are suitable for pasture and hay lands; but the soils are cold, retain water too long, and are apt to form bogs. The finer till, especially when the bowlders have been picked off, makes good agricultural land. Mechanical analyses of such soils by the United States Bureau of Soils are given in the following table, the large bowlders having been removed in each case:—

Diameter in Millimeters.	Conventional Names.	Bloomfield.	Enfield.	Hazardville.
2 to 1	Gravel	2	12.45	5.26
1 to 0.5	Coarse sand	3.35	11.86	8.66
0.5 to .25	Medium sand	8.60	13.98	18.83
.25 to .1	Fine sand	31.25	14.78	21.00
.1 to .05	Very fine sand	34.22	17.51	18.83
.05 to .01	Silt	4.35	8.20	8.70
.01 to .005	Fine silt	6.20	8.67	5.30
.005 to .0001	Clay	6.57	10.23	10.87
Loss at 110° C.		1.36	1.04	1.01
Loss on ignition		2.03	1.69	1.77
		99.93	100.41	100.23

Stratified drift is more readily cultivated than till, and is the soil used largely for tobacco and field crops in general. This assorted glacial material forms a soil which usually lacks richness, but is warm, easily tilled, holds much water, and is readily occupied by roots. Stratified drift is relatively fine in texture, as will be seen by the following analysis of soil from various places along the Connecticut River:—

Diameter in Millimeters.	Conventional Names.	Windsor.	East Longmeadow.	Burnside.	South Windsor.	Burnham.
2 to 1	Gravel	2.20	0.00	2.23	Trace	4.11
1 to 0.5	Coarse sand	7.51	.31	7.73	6.84	11.83
0.5 to .25	Medium	33.50	2.84	25.25	42.86	29.20
.25 to .1	Fine	32.05	63.10	29.00	33.00	24.45
.1 to .05	Very fine	13.50	29.15	25.40	7.73	12.72
.05 to .01	Silt	4.47	1.15	3.45	2.63	3.48
.01 to .005	Fine silt	1.75	.96	2.10	1.70	3.28
.005 to .0001	Clay	2.78	1.42	3.22	3.50	5.20
Loss at 110° C.		.80	.50	.77	.75	2.95
Loss on ignition		1.30	.90	1.27	1.54	2.81
		99.86	100.33	100.42	100.55	100.03

Clays.— The clays of central Connecticut are of glacial origin, and occur as parts of the till and as strata on the

floor of abandoned glacial lakes. The lake clays are by far the easiest to work, and are the only ones used. They occur in broad basin-like valleys along the Connecticut River and its tributaries, and are very similar in structure and composition. The clays are worked at Hartford, Windsor, South Windsor, Berlin, Middletown, Milldale, and North Haven. The Hartford clay forms the largest deposit, and extends up the Connecticut River into Massachusetts, with a width of from three to five miles. The thickness of the deposit varies considerably. At Parkville and West Hartford the depth varies from sixty to one hundred feet; at Windsor it is only from eighteen to forty feet. The northern part of the deposit is interrupted by rock ridges and drumlins, but clay over twenty feet deep extends as far as Thompsonville. The Berlin-Middletown deposit occupies a narrow, flat area along the Sebethe River, and averages thirty feet in thickness. The color of the clay is always reddish brown, thus differing entirely from the bluish gray clay of the Hartford region. Chemically the clays are very impure, only one-third or less being kaolin. The remainder is composed partly of fine quartz grains, with some feldspar, and numerous flakes of mica. The percentage of iron is sufficient to secure a deep red color to thoroughly burned clay. The clays of Connecticut are used almost exclusively for the making of common brick. The yards are clustered at several points from Thompsonville to North Haven. A report on the clay beds and their economic importance has been prepared by G. F. Loughlin.*

Water Supply.—The fact that the entire state of Connecticut has been overridden by the ice has greatly affected its water supply. The numerous lakes and swamps and many of the small streams owe their position and their very existence to the continental ice sheet. Of special economic value are the hundreds of lakes which constitute the principal water supply of cities and villages. Furthermore, the fact that the soil of Connecticut is of glacial origin de-

* This report is published as Bulletin No. 4 of this Survey.

termines its character as a reservoir for ground water. Wells sunk in the till are usually shallow, rarely over fifty feet in depth; and it is the practice to dig them but a few feet below the first prominent water horizon. Seventeen wells have been reported as being less than ten feet in depth, and yet they contained an abundant supply of water. In general the wells of till areas contain soft water, which varies in amount with the seasons. During an unusually dry summer, wells in the till in some sections of the state completely fail. The springs of the till-covered portion of the state for the most part afford soft water; and, like the wells, show their connection with the rainfall by their variation from year to year, and from season to season. Except in extraordinary seasons, however, the variation is slight, because in general the Connecticut rainfall is evenly distributed throughout the year.*

The stratified drift occupies a large part of the Central Lowlands of Connecticut, and also the valleys in the crystallines. It varies in depth from a few inches to over five hundred feet, and because of its prevailingly loose texture it forms a water reservoir of great capacity. Along sand plains, and in general throughout the Triassic area of Connecticut, water maintains a permanent level twenty to thirty feet below the surface; and the practice is to sink the wells some feet below this horizon, so that a reserve supply is always on hand. Where large quantities of water are required for manufacturing, swimming-pools, etc., several wells are sunk in close proximity, and connected with a single pump. Yale University uses twenty-four such wells to supply water for the gymnasium. Wells in stratified drift for the most part furnish an inexhaustible supply of pure water. Springs in the stratified drift are numerous, and vary in size according to the thickness and position of the sandy and clayey layers. Many are merely places where

* The rain-fall at New Haven is —

Spring,	11.13	inches.
Summer,	11.63	"
Autumn,	11.20	"
Winter,	10.93	"
Total,	44.89	"

the ground is wet from seepage; others furnish a sufficient supply for the farmhouse; and a few, like the Pequabuck Spring, near Bristol, afford water enough to form a brook.

Road Materials.— The best Macadam roads are made from the crushed rock quarried in the lava beds of the Triassic area of Connecticut; but good and much less expensive roads are made from glacial materials. The gravels and coarse sands of the stratified drift are spread so widely over the state that in general there is an abundant supply of these materials for road dressing. Till itself is not suitable for road-metal; but the bowlders which it contains furnish an abundant supply of suitable rock, and are conveniently located for crushing.

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Bulletin no. 7. Preliminary geological map of Connecticut. By H. E. Gregory and H. H. Robinson. Hartford, 1907.

39 pp., 2 maps (1 in pocket), 23^{cm}.

Gregory, Herbert Ernest, and ***Robinson, Henry Hollister.***

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State of Connecticut

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State Geological and Natural History Survey

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BULLETIN No. 7

HARTFORD PRESS
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1907

PRELIMINARY GEOLOGICAL MAP

OF

CONNECTICUT

By

HERBERT ERNEST GREGORY, Ph.D.,

Professor of Geology in Yale University

AND

HENRY HOLLISTER ROBINSON, C.E., Ph.D.,

Instructor in Geology in Yale University

HARTFORD PRESS

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PREFACE.

The small scale used for the Preliminary Geological Map of Connecticut makes it impracticable to represent all the rock groups, and to give credit on the map itself to the individuals and organizations whose assistance has made the map possible. The following pages have therefore been written to make the map more intelligible, and to explain its method of compilation, its value, and its deficiencies. This Bulletin has also been thought to be a suitable place to present a brief account of the history of geologic work in Connecticut. The imperfection of the map herewith presented is manifest, and the authors will be thankful for any information which will tend to make the knowledge of Connecticut geology more complete and more accessible.

HERBERT ERNEST GREGORY,
HENRY HOLLISTER ROBINSON.

New Haven, Conn., Dec. 23, 1906.

PRELIMINARY GEOLOGICAL MAP OF CONNECTICUT.

OUTLINE OF THE GEOLOGY OF CONNECTICUT.

A glance at the Connecticut geologic map which forms part of this Bulletin reveals the fact that the state consists of three geologic provinces: viz., a western portion composed of metamorphic crystalline rocks, an eastern portion of like character, and a central portion of sandstones and lavas. Topographically these areas constitute the Western Highland, the Eastern Highland, and the Connecticut and Farmington Valley Lowland. The rocks forming the Highlands are gneisses, schists, quartzites, and limestones of very great age, with intrusions of granitic, pegmatitic, and basic material. The characteristic structures present are the results of extreme metamorphism, and have been revealed by erosion of unknown thousands of feet of overlying rock. The sandstone, basalt, and diabase of the Lowland and of the small Pomperaug Valley area are of Triassic age, and rest uncomformably upon the underlying crystalline rocks.

Land doubtless existed in Connecticut before the earliest fossiliferous rocks were deposited, but the nature of such land areas is unknown. Whether originally igneous or sedimentary, or both, is undetermined; all that is certain regarding a pre-Cambrian formation like the Becket gneiss is that its present structure and composition are the results of a long series of changes which have completely altered the original rock mass. During Cambrian and Ordovician time, sandstone, shale, and limestone were being deposited in western Connecticut, forming the originals from which the Poughquag quartzite, Berkshire schist, and Stockbridge

limestone were later developed. The history of Connecticut during Silurian, Devonian, and Carboniferous time has not been deciphered. It is evident, however, that important and wide-spread disturbances occurred prior to Triassic time, and that injection and regional metamorphism have been important factors in the formation of the crystallines. As a result of these two processes, the rocks of the Highlands have been rendered crystalline, have been stretched and squeezed and drawn out into lines, and have suffered intrusion of granitic masses and dikes, pegmatite veins, masses and dikes of gabbro, amphibolite, etc. The rocks have, accordingly, in many cases, been so modified that their original character is destroyed. Fossils, which they may have contained, have been destroyed, and with them the means of determining the age of the rocks.

During Triassic time sandstones and shales were deposited over parts of Connecticut, and exist now in two areas shown on the map. The deposition of Triassic sediments was interrupted by at least three separate periods of volcanic activity, which produced the diabase and basalt from which have been carved the trap ridges that form such conspicuous features of the topography of central Connecticut. The lavas and sandstones were at a later date broken into blocks which were tilted toward the southeast.

The last great epoch in the geologic history of Connecticut was the Glacial age. Ice sheets covered the entire state; and in their advance southward the glaciers scoured and grooved the rock, reduced irregularities of topography, and carried much of the surface covering beyond the borders of the state. When the ice retreated, masses of loosened rock waste were left unevenly distributed over the state as gravel, hard-pan, bowlders, etc.

On the geological map no account is taken of the presence of Glacial material, but the state is divided into rock formations as they are thought to exist beneath the surface covering.

A fuller treatment of the Geology of Connecticut will be found in Bulletin No. 6.

SKETCH OF THE HISTORY OF CONNECTICUT GEOLOGY

The geology of Connecticut has attracted the attention of scientific men for nearly a century, and the first geologic map issued in this country distinguishes the Triassic sandstones from the crystallines. From the time when the first paper on the Mineralogy of the Town of New Haven was published by Silliman, in 1810, valuable contributions to the geology of the state have been made by state and national surveys and by private individuals.

CONNECTICUT GEOLOGICAL SURVEYS.

The teaching of Benjamin Silliman at Yale (1804-1853), and the founding of the *American Journal of Science,* in 1818, served to arouse great interest in the study of natural history in America. This interest expressed itself in provision for geological instruction in the colleges, and in the investigation of the natural resources of the various states by commissions appointed by the legislatures. North Carolina took the lead and established a survey in 1823. South Carolina appointed Professor Vanuxem State Geologist the following year. In 1830 Edward Hitchcock was appointed State Geologist of Massachusetts, and two reports were issued, in 1832 and 1833, respectively. Tennessee established a survey in 1831, New Jersey and Virginia in 1835, Maine, New York, and Pennsylvania in 1836, Kentucky in 1838, New Hampshire and Rhode Island in 1839. The first geological survey of Connecticut was established in 1835.

The Percival Survey.— The credit for the establishment of the first Geological Survey of Connecticut belongs to

Governor Edwards, who, after consultation with Silliman, Percival, and others, brought the matter before the legislature, urged action, and afterwards exerted his influence in favor of allowing geologists adequate time and means for prosecuting the work. In his annual message for 1835, Governor Edwards says:—

"The mineralogical treasures which have been developed within a few years and which are constantly coming to light in different parts of our country, give us reason to believe that we have not as yet availed ourselves to the extent that we might of this source of wealth, and suggests the expediency of a more systematic examination than has hitherto taken place. In some instances this has been done under the public patronage, and by public authority. An examination of the kind in our State might lead to some important discoveries. An accurate and thorough geological and mineralogical survey by scientific men, if it should not result in any immediate discoveries of moment, would at least have the effect of aiding individuals in their future researches on their own lands. Much labor has been expended, and money wasted, in the search after metals and minerals, which a knowledge of those substances and the relative position they uniformly occupy, would have shown to be useless.

"The geological character of a country indicates its topographical features; and a geological map would serve as a guide in the examination and selection of routes for railroads, and canals, and internal improvements of every kind, the location of which depends on the topical features of the country through which they pass. A survey of the kind referred to, would furnish every individual with such information respecting his possessions, as would guard him against the wiles of prowling speculators. Much labor has been bestowed on this subject, and much information collected by individuals in different sections of the state, and it is important that this information should be embodied and preserved; the expense would be trifling, and bear but a very small proportion to the benefits which may be derived

from it. This is a subject in which the whole community has a deep interest, and it is recommended that immediate measures be taken for its accomplishment. Similar surveys have been already had in some of the states; and the attention of others is turned to the subject. Let us not be deficient on our part; we have heretofore furnished, and we can still furnish, our full quota to those economical and scientific researches which seem to be the order of the day."[2]

In accordance with the above recommendation, the legislature passed the following resolution:—

"Resolved, That the Governor be and is hereby authorized to appoint a committee of suitable persons to make a geological survey of the state of Connecticut, and to report the same to the General Assembly at their May Session of 1836.

"Resolved, That the property of such survey shall be in and belong to the State, and shall be disposed of as the General Assembly may direct."

The charge of the survey was offered to Silliman, who refused it, as did also Percival, and later Shepard. Finally, at the urgent request of Governor Edwards and of Shepard, it was arranged that Percival should undertake the study of the general geology of the state, and Shepard the study of the mineralogy and economic geology. These two men accordingly took up the work under the following official appointment:—

"Henry W. Edwards, Governor of the State of Connecticut, to James Gates Percival and Charles Upham Shepard,—greeting: Pursuant to resolves passed by the General Assembly of Connecticut, at Hartford, in May, 1835, I do appoint you, said Percival and Shepard, a committee to make and complete the survey and report in said resolves, to perform the duties thereof, and obey the instructions from time to time received from the proper authority.

"Given under my hand and official seal, at New Haven, this 15th day of June, A. D. 1835.

HENRY W. EDWARDS."

The reports of Percival and Shepard were accepted by the legislature of 1836, and the Survey was continued for another year. The work assigned to Shepard was largely a matter of collecting and classifying, and after some six months' work that officer handed in "A Report on the Geological Survey of Connecticut," dated May 15, 1837. The committee to which Shepard's work was referred recommended its publication in the following report:—

"The joint committee on the Geological and Mineralogical Survey of the State, to whom was referred the Special Message of the Governor and the accompanying papers relating to the mineralogical department of said survey, having had the same under their consideration, Report,

"That Professor Shepard has brought his examination into the mineralogy of the State to a close, and the results of his labors have been before us in a highly interesting and valuable Report. This Report, embracing the statistics of all our present mineral resources, the condition of our mines, quarries, and diggings of every description, and suggestions as to the most profitable manner of working them both to the proprietors and the public, all of which are capable of immediate application,—your committee recommend should be immediately published. * * * *

"The document will constitute an 8vo volume, or pamphlet, of one hundred and fifty pages; and, if published in the style in which these surveys are done in other states, will cost about twenty-five cents a copy. Your committee, therefore, recommend an appropriation of a sum of money not exceeding five hundred dollars, or such less sum as his Excellency the Governor may contract for, for the publication of two thousand copies. That, of this number, the Governor be authorized to distribute copies in the following manner:—

"Two copies to the library of Congress; two copies to the Governor of every state in the Union; two copies to the library of Yale College, of Washington College, and of the Wesleyan University of this state,—and to each of the State Officers; one copy to each of the Judges of the

Supreme Court; one copy to each of the Judges of the County Court and to each Probate Judge of this State, who are not members of this Legislature; one copy to each member of the two Houses of the present Legislature; one copy to the town clerk of every town in the State; fifty copies to remain at the disposal of Prof. Shepard, and the same number at the disposal of his Excellency, the Governor."

The resolution as finally passed by the legislature is as follows:

"Resolved by this Assembly, That two thousand copies of Prof. Shepard's Report on the Mineralogy of the State be published under the superintendence of the author, and that a sum of money not exceeding five hundred dollars be appropriated to defray the expenses,—and that the Comptroller of public accounts is hereby authorized to draw an order on the Treasurer for such sum, not exceeding five hundred dollars, to be paid out of any money not otherwise appropriated,—and his Excellency, the Governor, is hereby appointed Commissioner to see the object of this resolution effected."

The report was issued the same year.

The task which Percival had undertaken could not be thus easily disposed of. It involved a determination of rock types with their endless variation, a careful tabulation of dips and strikes, and the preparation of a detailed geological map of an unknown region. Percival worked at his task year after year, while the legislature, and especially Governor Ellsworth, became more and more impatient. The Governor and Percival were evidently working at cross purposes; the former wanted information regarding the supposed mineral wealth of the state, while Percival had set out to solve the problems relating to the composition and complicated structure of the rocks. In the spring of 1838 he presented an exhaustive report,* but was unwilling to have it published until he had verified his statements by an examination of his newly collected material.

* No trace of this manuscript has been found.

Work was continued during 1838, 1839, 1840, and 1841; and during this time the misunderstanding with the state authorities became more acute. Finally the small state appropriation was cut off, and Percival, seeing that time was not to be allowed for a careful study of his material, decided reluctantly to prepare such a report as the circumstances would allow.

The "Report on the Geology of the State of Connecticut; by James G. Percival," was written in the spring of 1842; in May an appropriation of $1,500 was made for printing one thousand copies, and the book appeared before the close of the year. In the preface the author remarks:—

"The report which follows is but a hasty outline, written mainly from recollection, with only occasional reference to my materials, and under circumstances little calculated for cool consideration. It was written, however, with an intention to state nothing of the truth or probability of which I did not feel satisfied. None can regret more than I do, its imperfection; * * *"

Percival had devoted more than five years of his life to this work, and had received on the average $600 per year, out of which all expenses had to be paid. Under these circumstances, it is not creditable to Governor Ellsworth's administration that another year's appropriation was refused, and the State Geologist thereby forced to write his report without proper use of his voluminous notes and extensive collections.

The method of conducting the geological survey is explained by Percival in the preface to his report:—

"During the summer of that year [1835], I travelled, with Prof. Shepard, through every town in the State, but the short period then allowed me, only enabled me to make a general preparatory reconnoissance. An additional appropriation for the continuance of the survey, was made by the Legislature, in the session of 1836. I then commenced, by myself, a regular plan of survey, by sections across the State, from East to West, at average intervals of four miles. This I accomplished in nearly eight months

constant travel. In the session of 1837, a further appropriation was made to enable me to complete the survey, after having prepared a report of my previous explorations. This report I completed and submitted, Jan. 1st, 1838. Before commencing a re-survey of the State, I undertook an exploration of the Trap dikes traversing the Primary, which I traced throughout their whole extent. Before engaging in the survey (in 1834), I had particularly explored the different ranges of Trap connected with the two Secondary formations in the State, and had traced them out so fully, that only two or three unimportant localities have since occurred to me. After I had completed my examination of the Trap dikes in the Primary, I commenced a re-survey of the State, by sections from East to West, as before, in the intervals between my former sections, thus reducing the average distance of my sections to two miles, and bringing myself in contact with each of the 4,600 square miles in the State. This does not include my general reconnoissance the first season, nor my particular exploration of the Trap connected both with the Secondary and Primary. In my first regular survey, I had ascertained the general system of arrangement in the rocks of the State, and had prepared myself for a more discriminating investigation of the different formations. The second survey I consequently made more minutely, and devoted to it a much greater length of time. In these two surveys I had taken ample notes, in which I had marked the character and relative arrangement of the rocks in the different localities examined, as well as the direction and dip of the strata in each. I had also collected illustrative specimens in most of the localities, all of which are so arranged and labelled, that the precise locality and relation of each can, by reference to my notes, be at once determined. The number of localities from which I have collected specimens, I have estimated at nearly 8000; the records of dips and bearings are still more numerous."

Percival's Report on the Geology of Connecticut is not a readable book; it does not contain theories and inferences and bits of lively description, but merely dry facts grouped

geographically. It is about the last book which a poet, one of the most celebrated of his time, would be expected to write. Accuracy and keenness of observation and distinctness of representation are, however, prime requisites for lasting scientific work, and in these qualities Percival excelled. The more the modern geologist becomes familiar with the involved structures and exasperating variations found within the metamorphic rocks of the state, the more respect and admiration he has for Percival's discrimination and skill in delineation. It is doubtful if ever a more accurate discrimination of the various members of a complicated series of crystalline rocks on field evidence alone was ever accomplished.

The Connecticut Topographical Survey.— The preparation of a satisfactory base map of Connecticut was not undertaken until the attention of the legislature was called to the need of such a map by Governor Bulkeley, in 1889. In his message for that year the Governor says:—

" My attention has been called to the fact that the state has never secured an official and accurate topographical survey and map of the state, and that a favorable opportunity now exists through the co-operation of the general government, to secure such a survey and map at a moderate expense. You will be asked to give this subject your serious consideration. Adjoining states have taken advantage of the work of the United States Geological Survey, and in Massachusetts and Rhode Island the field work of the surveys is completed. The desirability of securing an accurate map of the state cannot, I think, for a moment, be doubted."

The following resolution for the establishment of a topographic survey originated with Judge S. W. Adams of Hartford, was passed by the legislature, and was approved early in June, 1889:—

" Resolved by this Assembly: That the Governor be and he is hereby authorized to appoint a Commission, to consist of three citizens of this State, qualified by education and experience in topographical science, to confer with the di-

rector or representative of the United States Geological Survey, and to accept its co-operation with this State in the preparation and completion of a contour topographical survey and map of this State, which is hereby authorized to be made, and it is hereby provided that said map shall accurately show all town and county boundary lines in this State as existing at the time of its completion. Said commission shall serve without pay, but all its necessary expenses shall be approved by the comptroller, and paid out of the State treasury. Said commission shall have power to arrange with the director or representative of the United States Geological Survey concerning the survey and map herein provided, for its scale, method of execution, form, and all details of the work, in behalf of this State, and may accept or reject the work presented by the United States Geological Survey. Said commission may expend, in the prosecution of this work, a sum equal to that which shall be expended therein by the United States Geological Survey, but the total cost of this survey to this state shall not exceed the sum of twenty-five thousand dollars."

On June 12th there was appropriated "for a Topographical Survey of the State of Connecticut, $25,000, provided said survey together with all costs for labor and expenses of the commission appointed therefor and all other expenses connected therewith can be completed for that sum."*

On June 19th, 1889, William H. Brewer of New Haven, James H. Chapin of Meriden, and John W. Bacon of Danbury, were appointed Commissioners of the State Topographical Survey.

In July, 1889, work on the state map was actively begun under the following contract:—

"Agreement between the Commissioners of the State of Connecticut and the Director of the United States Geological Survey, for the construction of a Topographical Map of Connecticut:

"1. The preparation of the map shall be placed under the supervision of the director of the United States Geolog-

* The amount actually expended was $24,599.21.

ical Survey, who shall determine the methods of survey and map construction.

"2. The work shall be based upon the triangulation of the United States Coast and Geodetic Survey, and wherever this is deficient it shall be supplemented by the United States Geological Survey.

"3. The survey shall be executed in a manner sufficiently elaborate to prepare a map upon a scale of 1 : 62,500, exhibiting the hydrography, hypsography, and public culture, and including all town and county boundary lines in this state as established at the time of its completion, and the preliminary field maps shall be on such a scale as the director of the United States Geological Survey may select to secure accuracy in the construction of the final map.

"4. The hypsography shall be shown by contour lines with vertical intervals of 20 ft.

"5. The heights of important points, including dams, shall be determined and furnished to the Commissioners of Connecticut.

"6. The outlines of wood areas shall be represented upon proofs of the engraved map to be furnished the Commissioners of Connecticut. * * *

"9. The resulting map shall fully recognize the co-operation of the State of Connecticut.

"10. When the work is completed the Commissioners of Connecticut shall be furnished by the United States Geological Survey with photographic copies of the manuscript sheets; and when the engraving is complete said commissioners shall be furnished by the said Survey with electro-copper plates of the sheets of the map, without cost to the State in excess of the twenty-five thousand (25,000) dollars appropriated by the State, less the necessary expenses of the State Commission."

By a subsequent agreement country houses were indicated on the map, an undertaking not heretofore attempted by the Geological Survey.

When the Government field parties began work in Connecticut, they made use of the previously established signal stations of the United States Coast and Geodetic Survey;

for example, Mount Carmel, Ivy Mountain, Bolton Mountain. This triangulation was supplemented by six weeks' work of S. S. Gannett; and 145 miles of levels were run by W. R. Atkinson. During 1889-90 the entire western half of the state (2,477 square miles) was mapped by parties in charge of J. H. Jennings, E. W. F. Natter, E. B. Clark, W. R. Atkinson, and M. B. Lambert; four topographic parties were at work during the official year 1890-91, under J. H. Jennings, W. R. Atkinson, F. P. Gulliver, and E. B. Clark. G. L. Johnson and G. E. Hyde had charge of parties for short periods. By December, 1890, all the state had been surveyed, with the exception of the Norwich sheet, which was completed in 1891.* The engraving of the maps began when the result of the field work was tabulated, and by the close of 1893 all the plates for the 33 sheets into which the Connecticut Topographic Atlas is divided, were engraved.

The printing and distribution of the maps was provided for by the following resolution, approved March 23d, 1893:—

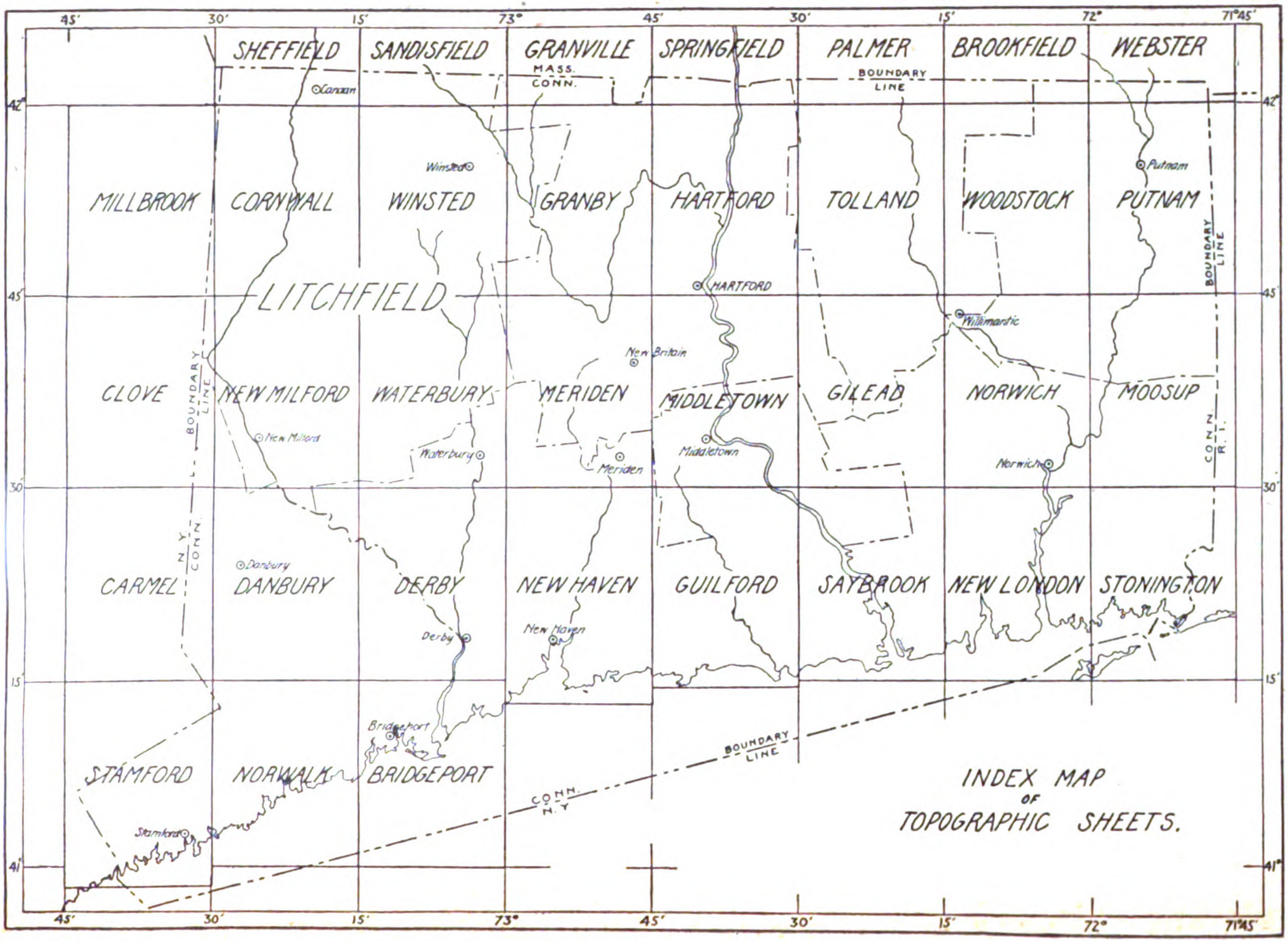
"That the sum of $5,000.00† be appropriated for the printing and distribution of the atlas sheets and maps of the State of Connecticut, under the direction of the Commissioners of the State Topographical Survey. The distribution and sale of said atlas sheets and maps shall be in charge of the State Librarian, in accordance with such prices and regulations as may be prescribed by said commissioners."‡

The commissioners arranged for the printing of 2,000 sets of separate atlas sheets, on a scale of 1:62,500 (approximately one mile to the inch), and also 1,000 copies of a wall map, on a scale of 1:125,000 (approximately two miles to the inch). Seventeen atlas sheets are entirely within the state, while seventeen others include parts of

* The area of Connecticut, exclusive of the waters of Long Island Sound and of bays more than 1,000 ft. in width, was determined to be 5,047 square miles. Later measurements make the area 4,965 square miles, of which 4,820 square miles are land surface and 145 square miles water surface. (See U. S. Geol. Surv. Bull., 302, 1906.

† The amount expended was approximately $3,400.

‡ The Topographic Map is for sale by the State Librarian. Single sheets may be had for 10 cents each, postpaid, and the set of 33 sheets bound or unbound for $3.00 net. The Topographic Map of the entire state on the scale of two miles to the inch, mounted on rollers and muslin-lined, costs $1.00 net.



SHEFFIELD
SANDISFIELD
GRANVILLE
SPRINGFIELD
PALMER
BROOKFIELD
WEBSTER
MASS.
CONN.
BOUNDARY LINE
Canaan
Winsted
Putnam
MILLBROOK
CORNWALL
WINSTED
GRANBY
HARTFORD
TOLLAND
WOODSTOCK
PUTNAM
LITCHFIELD
HARTFORD
Willimantic
New Britain
CLOVE
NEW MILFORD
WATERBURY
MERIDEN
MIDDLETOWN
GILEAD
NORWICH
MOOSUP
New Milford
Waterbury
Meriden
Middletown
Norwich
CONN. R.I.
N.Y. CONN.
Danbury
CARMEL
DANBURY
DERBY
NEW HAVEN
GUILFORD
SAYBROOK
NEW LONDON
STONINGTON
Derby
New Haven
Bridgeport
STAMFORD
NORWALK
BRIDGEPORT
CONN. N.Y.
Stamford
INDEX MAP OF TOPOGRAPHIC SHEETS.
45'
30'
15'
73°
72°
71°45'
42°
41°

adjoining states. The location and areal extent of the sheets comprising the Connecticut Topographical Atlas are shown on the accompanying map.*

Geological and Natural History Survey of 1903.— The State of Connecticut undertook no geological work from 1842 to 1903. However, during the intervening time much work had been carried on, chiefly by Professor J. D. Dana, and by officers of the United States Geological Survey; and of late years the need of some systematic examination of the resources of the state became more and more apparent to teachers, scientific workers, and men of affairs. A proposition to organize a State Survey was informally discussed during 1901-1902; but the first definite step looking to its establishment was the presentation of a bill in the January session, 1903, of the General Assembly, prepared by the Hartford Scientific Society. The following substitute for the original bill was approved June 3, 1903:—

"Be it enacted by the Senate and House of Representatives in General Assembly convened:

"Section 1. There is hereby established a state geological and natural history survey, which shall be under the direction of a commission composed of the governor, the president of Yale University, the president of Wesleyan University, the president of Trinity College, and the president of the Connecticut Agricultural College, or so many of them as shall accept said office, who shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties; and the said commissioners shall have general charge of the survey, and shall appoint as superintendent of the same a scientist of established reputation, and such assistants and employes as they may deem necessary; and they shall also determine the compensation of all persons employed by the survey and may remove them at pleasure.

* As originally issued, the western boundary of the Cornwall sheet was coincident with the state line. Maps published since 1902 show parts of Sharon and Kent, on the Millbrook (New York) sheet. There has recently been issued a map (The Litchfield Sheet) on a scale of two miles to the inch, including the area of the Cornwall, Winsted, New Milford, and Waterbury sheets.

"Sec. 2. Said survey shall have for its objects:

"(1) An examination of the geological formation of the state, with special reference to its economic products, to wit, building stones, clays, ores, and other mineral substances.

"(2) An examination of the animal and plant life of the state, with special reference to its economic and educational value.

"(3) The preparation of special maps to illustrate the resources of the state.

"(4) The preparation of special reports, with necessary illustrations and maps, which shall embrace both a general and detailed description of the geology and natural history of the state.

"Sec. 3. The said commissioners shall cause to be pre pared a report to the general assembly before each meeting of the same, showing the progress and condition of the survey, together with such other information as they may deem necessary and useful or as the general assembly may require.

"Sec. 4. The regular and special reports of the survey, with proper illustrations and maps, shall be prepared for publication, and when printed the reports shall be distributed or sold by the commissioners as the interests of the state and of science demand, and all moneys obtained by the sale of the reports shall be paid into the state treasury.

"Sec. 5. All material collected, after having served the purposes of the survey, shall be distributed by the commissioners to the educational institutions of the state in such manner as to be of the greatest advantage to the educational interests of the state, or, if deemed advisable by said commissioners, the whole or any part of such material shall be put on permanent exhibition.

"Sec. 6. The sum of three thousand dollars, or so much thereof as may be necessary, is hereby appropriated out of any money in the treasury not otherwise appropriated, for the purpose of carrying out the provisions of this act."

The first meeting of the Commissioners was held June

15, 1903, and at the meeting of June 25, 1903, Professor William North Rice of Wesleyan University was appointed superintendent. The plan of organization and the work undertaken are explained in Bulletin No. 1.

WORK OF THE UNITED STATES GEOLOGICAL SURVEY IN CONNECTICUT.*

The United States Geological Survey was established March 3, 1879; and by an act of August 7, 1882, its authority was extended over the entire area of the United States. The first recorded work done within Connecticut was an examination of feldspar quarries by F. W. Clarke, in September, 1884.

In the year 1885-86 Raphael Pumpelly was given charge of Archæan Geology of the Eastern United States, and Professor W. M. Davis, one of his assistants, studied the sandstones and traps of the Connecticut Valley, and a paper entitled "The Structure of the Triassic Formation of the Connecticut Valley," by Professor Davis, appears in the Annual Report for this year.

1887-88. W. M. Davis continued his study of the Triassic eruptives.

1889-90. J. S. Newberry finished his work on the fossil plants of the Connecticut Triassic. W. M. Davis began detailed mapping of the Triassic rocks. In this work he was assisted by E. O. Hovey, J. A. Merrill, H. L. Rich, and S. W. Loper, the last named assistant paying particular attention to the fossiliferous black shales.

1890-91. Davis continued his work on the Triassic, and was assisted by E. O. Hovey in the New Haven region, by J. A. Merrill in the Meriden region, by H. L. Rich in the Woodbury-Southbury district, and by S. W. Loper. The glacial geology of Connecticut was in charge of Professor N. S. Shaler, and certain topographic sheets were mapped in a preliminary way by his assistants, R. E. Dodge, M. A. Read, J. B. Woodworth, and E. T. Brewster.

1891-92. The work on the Triassic was continued by

*For an account of the topographic work in Connecticut done jointly by the U. S. Geological Survey and the State of Connecticut, see page 16.

W. M. Davis, and the following assistants:— H. B. Kümmel, who studied the geology of the Hartford and Granby topographic sheets; W. N. Rice, who examined the area covered by the Middletown sheet; S. W. Loper, who continued his investigation of the black shales; and L. S. Griswold, who made a special examination of the Triassic boundaries and of districts of complicated faulting. Under the direction of Professor Shaler, the surface geology of five sheets in Connecticut was mapped by R. E. Dodge, L. H. Davis, C. R. Eastman, E. T. Brewster, and J. H. Ropes. As an extension of work done in Massachusetts, Professor B. K. Emerson, assisted by Fred A. Peck, began areal mapping on the Granby and Tolland topographic sheets.

1892-93. W. M. Davis, assisted by L. S. Griswold, W. N. Rice, and others, completed field work on the Triassic formation. Professor Shaler reported that the glacial geology of the following sheets had been mapped:— New Milford, New Haven, Derby, Danbury, Winsted, New London, Tolland, Woodstock, Norwich, Gilead, Waterbury, Cornwall.

1893-94. Under the direction of Professor Shaler, R. E. Dodge completed a glacial map of the Moosup, Putnam, and Stamford sheets, and L. H. Davis surveyed the Bridgeport and Norwalk sheets.

1895-96. During this year the work on the Hoosac Mountain region, which was begun in 1885, was extended southward, and Professor W. H. Hobbs began an areal map of the Cornwall topographic sheet.

1896-97. W. H. Hobbs completed a map of the Cornwall sheet, and made a reconnaissance of the New Milford sheet. Davis's paper on the "Triassic Formation of Connecticut" appeared in the Annual Report of this year.

1899-1900. W. H. Hobbs, assisted by H. H. Robinson, was engaged in areal work on the Danbury, Derby, Winsted, New Milford, and Waterbury sheets. A detailed study was also made of the Triassic area of the Pomperaug Valley. In the Annual Report for this year appears "The Newark System of the Pomperaug Valley, Connecticut," by William

Herbert Hobbs. Herbert E. Gregory began work on the crystalline rocks of the Granby and Meriden sheets.

1900-1901. Two hundred square miles of the Danbury, Derby, Norwalk, and Bridgeport sheets were mapped by Professor W. H. Hobbs. A paper on "The Old Tungsten Mine at Trumbull, Connecticut," by William H. Hobbs, appears in the Annual Report for this year. Herbert E. Gregory, in conjunction with L. G. Westgate, completed a survey of the crystalline rocks of the Hartford and Middletown sheets, and made a reconnaissance of the Tolland sheet.

1901-1902. C. R. Van Hise, assisted by W. H. Smith, made a general study of the stratigraphy of western Connecticut. W. H. Hobbs, assisted by S. H. Ball and A. F. Smith, was at work on the Danbury, Derby, Norwalk, and Bridgeport sheets, and completed the areal mapping of Connecticut west of the 73d meridian. Herbert E. Gregory, assisted by C. H. Warren and W. E. Ford, Jr., made a preliminary map of the Tolland, Woodstock, Putnam, Gilead, Norwich, and Moosup sheets.

1902-1903. Herbert E. Gregory completed the areal work previously begun on the Granby and Meriden sheets. W. E. Ford, Jr., assistant, made a study of the granite-gneiss in the vicinity of Stony Creek.

1903-1904. Professor Hobbs made a study of the iron ore deposits on the Cornwall, New Milford, Winsted, and Waterbury sheets. Herbert E. Gregory, assisted by G. F. Loughlin and C. J. Sarle, mapped the Glacial deposits of the Granby, Meriden, Hartford, and Middletown sheets. Professor Gregory also collected well and spring records, and began the study of the underground waters of the state. The results of this work appear in Water Supply and Irrigation Papers, Nos. 102 and 114. In this year a systematic study of the streams of the state was begun by N. C. Grover. Gaging stations had been previously established on the Housatonic River (1900), and on the Byram and Mianus (1902).

1904-1905. A gaging station was established on the Shetucket River near Willimantic, and a study of the

Thames River drainage basin was begun. Other rivers examined are the Connecticut and the Housatonic. Mr. E. E. Ellis, under the general direction of Herbert E. Gregory, made a study of the occurrence of water in the crystalline rocks of the state.

As the result of recent work, the following manuscripts have been prepared by officers of the United States Geological Survey, and submitted for publication:—

The Litchfield Folio (including the Cornwall, Winsted, New Milford, and Waterbury topographic sheets), containing geologic maps and descriptive text; by William Herbert Hobbs.

The Farmington Folio (including the Granby, Hartford, Meriden, and Middletown sheets), containing maps and text; by Herbert E. Gregory.

The Underground Waters of Connecticut; by Herbert E. Gregory and E. E. Ellis.

WORK OF THE BUREAU OF SOILS.

The first Report of Field Operations of the Division of Soils (now Bureau of Soils) of the United States Department of Agriculture, was for the year 1899, and contains an account of a soil survey made in the Connecticut Valley by Clarence W. Dorsey and J. A. Bonsteel. The area mapped and described is located on the Hartford and Springfield topographic sheets. In 1903 soil mapping was continued to include practically all of the Triassic north of a line through Berlin.

WORK OF PRIVATE INDIVIDUALS.

In addition to the officers of state and national surveys, many private individuals have made contributions to the geology of Connecticut. Foremost among these geologists are Benjamin Silliman and James D. Dana.

In the Transactions of the Connecticut Academy of Arts and Sciences, Vol. I (1810), there appeared an article by Benjamin Silliman, entitled, "Sketch of the Mineralogy of the Town of New Haven." This paper was followed by

others dealing with the trap rock of New Haven, Hartford, Talcott Mountain, and Woodbury, and by articles descriptive of minerals and fossils. In his paper on the "Igneous Origin of some Trap Rocks,"* Professor Silliman discusses contact metamorphism and the volcanic nature of the basalt near Hartford, and suggests some of the principles whose application by Davis served to discriminate the contemporaneous from the intrusive traps.

James D. Dana began his contributions to Connecticut geology in 1843 by a discussion of the trap rocks. Many papers followed, dealing with the sandstones, the igneous rocks, and the glacial deposits of the Connecticut Valley and of New Haven. Perhaps the most valuable contribution made by Professor Dana to the geology of his adopted state was a study of the limestone, quartzite, and schists of the New York-Connecticut border. The structure of this region is involved, and the discussion concerning the age and structural relations of the rocks constituted the "Taconic Question" which occupies so large a space in the geologic literature of New England and New York. The mistaken field observations of Emmons, reinforced by *ex cathedra* discussions by Hunt and Marcou, tended to confuse an already difficult problem. Dana, aided later by Walcott and Merrill, settled the Taconic question by determining the structure and age of the Berkshire schist and of the Stockbridge limestone.

W. W. Mather has to his credit the first extensive piece of detailed areal mapping of the crystalline rocks. His "Sketch of the Geology and Mineralogy of New London and Windham County," accompanied by a colored geologic map, appeared in 1834. In 1875, E. S. Dana prepared a paper on the Trap Rocks of the Connecticut Valley, which was the first important memoir on petrography published in this country.

Before his connection with the United States Geological Survey, Professor W. M. Davis published papers in which the structural relations and origin of the Triassic traps were

* *Am. Journal of Science*, series 1, vol. XVII, pp. 119-132.

clearly defined. A paper by Professor W. N. Rice on the Trap and Sandstone in the Gorge of the Farmington River at Tariffville, published in 1886, was an important aid in determining the extrusive origin of certain trap rocks.

Papers dealing with the paleontology of Connecticut have been issued by E. Hitchcock, J. D. Dana, Marsh, Newberry, Lull, and others.

THE GEOLOGICAL MAP OF 1907.

The geological map herewith presented was prepared by Herbert E. Gregory and H. H. Robinson, at the request of the Superintendent of the Geological and Natural History Survey.

Geographic Base.— The base map used for the representation of the geologic features is the topographic map of 1893. For recording facts in the field the large scale atlas sheets were used. The data thus indicated were transferred by the authors to the small scale (2 m.=1 in.) State map, and this map was still further reduced by the engraver to the scale of the present map (4 m.=1 in.).

Geologic Maps Used in Compilation.— In the preparation of the geologic map, the manuscript maps and published maps of the following geologists have been used:—

William Herbert Hobbs: A manuscript map of Connecticut west of the 73d Meridian, with the exception of the area around Stamford. This map is the result of work for the United States Geological Survey (see pp. 24-26), which it is expected will appear as the Litchfield Folio and the Fairfield Folio. The authors of the present map have departed from the manuscript map of Hobbs in a few instances, particularly as to the extent of the Danbury granodiorite-gneiss.

William Morris Davis: Map of the Triassic Area of Connecticut, United States Geological Survey, 18th Ann. Rep., Pl. II. This map, of which the original manuscript copy was supplied by Professor Davis, has been used in its entirety, except where modified by the work of Herbert E. Gregory on the Farmington Folio.

Herbert Ernest Gregory: A manuscript map of Connecticut east of the 73d Meridian, with the exception of an area

in the vicinity of Middletown and of the shore line from New Haven to Mystic. This map is the result of work under the auspices of the United States Geological Survey (1899-1900, 1900-1901, 1901-1902), and of the Connecticut Geological and Natural History Survey (1904-05).

Henry Hollister Robinson: Manuscript map of the sheets bordering Long Island Sound from Lighthouse Point to Mystic; based on work done under the auspices of the Connecticut Geological and Natural History Survey.

Lewis Gardner Westgate: A manuscript map of the crystalline rocks of the southeast corner of the Middletown sheet.

James Gates Percival: In a number of localities where the work of the field parties did not join, or where the facts could not be determined without further field work, the map of the Percival Survey of 1842 was followed.

Scope of the Map.— Only bed-rock formations have been represented on the map. The cover of till, stratified drift, lacustrine deposits, etc., has been entirely omitted. Moreover, many areas of easily recognized rock have been omitted from the map on account of their small size. This applies to the smaller areas of amphibolite, to pegmatite, quartz veins, soapstone, serpentine, etc. An exception has been made in favor of the diabase dikes in the crystallines.

Geologic Boundaries.— The drawing of accurate geologic boundaries is in many cases made impossible by two facts: the mantle of drift, which in many places covers all contacts; and the evident gradation between adjoining formations. More detailed work will doubtless result in determining more precisely the extent of certain formations, but in some cases the boundaries will probably never be located with assurance.

Nomenclature.— The names applied to the formations are those used by the various field parties, and indicate areas of rock of like composition and structure. The equivalence of a formation within the state with one outside has not been

assumed, except where the authors are personally familiar with both areas.

Aid from the United States Geological Survey.— The present map has been made possible by the kindness of the United States Geological Survey, and the authors wish to express their thanks for permission to use freely the unpublished material of Messrs. Hobbs and Gregory.

Value of the Map.— The authors wish it distinctly understood that the map of 1907 is not in any sense a final or complete map. The material at hand in published reports and unpublished notes and manuscript maps has been utilized, but with little effort to reconcile divergent views of various workers, and no attempt at correlation. The most reliable parts of the map are those based on work done by the United States Geological Survey.* The map of 1907 is not designed especially to furnish new material for scientific experts, but aims to bring together the scattered geologic data which have been accumulating since the publication of Percival's map in 1842. It is hoped that the publication of even an incomplete map will be found acceptable to the people of the state.

Explanation of Base Map and Color Scheme.— The data for the geographic base of the Connecticut geologic map of 1907 were taken from the United States Geological Survey topographic map of the state, first published in 1893, on a scale of 1 : 125,000. The principal difference lies in the omission of a large number of names, small streams, and some of the roads. The roads are indicated by fine black lines; water is blue; topography is shown by contour lines with a vertical interval of 100 feet, and is in brown. A small circle within a town indicates the location of the village or city which has the same name as the town. The round black dots on the railroads locate stations, and these were put on from the time-tables (January, 1906) published by the railroads. Location of quarries (granite, sandstone, marble, etc.) is shown by black crossed hammers.

* See page 23.

The color scheme adopted for the map was devised with reference only to the geology of Connecticut. Of the thirty-eight formations (excluding the Triassic) shown on the map, the geologic age of only four has been assigned. These four known formations are all in the Western Crystallines, occupying about one-third of that area, so that the entire mass of the Eastern Crystallines is of unknown age. It did not seem advisable, therefore, to follow any conventional color scheme for bringing out age distinctions; and, instead, an attempt has been made to make a distinction between the several principal groups of formations petrologically considered.

SUMMARY OF GEOLOGICAL FORMATIONS.

For convenience in using the accompanying geological map, the following brief statement is given of the important features of the different formations. More complete descriptions are to be found in Bulletin No. 6.

1. Poughquag Quartzite.— The formation consists of two types: the massive granular, composed largely of quartz and feldspar; and the schistose, in which a considerable amount of mica is present. Origin, sedimentary. Age, Cambrian.

2. Stockbridge Limestone.— A light gray to white marble of medium grain; composed largely of calcite. At some localities it becomes dolomitic, passing into a true dolomite. Origin, sedimentary. Age, Cambro-Ordovician.

3. Berkshire Schist.— Is generally a gray or greenish gray muscovite-biotite schist, with rusty foliation planes, and usually closely folded. Porphyritic minerals developed in the rock are usually feldspar and garnet; but staurolite, biotite, and tourmaline also occur. Origin, sedimentary. Age, Upper Ordovician.

4. Becket Gneiss.— It is light gray in color, of firm texture, and has a uniform banded structure. In many places the rock is highly quartzose and granular. Included within the formation are many veins of quartz and pegmatite. Supposed to be of pre-Cambrian age.

5. Hartland Schist.— Rock is everywhere a mica schist of definable character, but exhibits great variation in texture, composition, and field appearance. Its aspect has been rendered still more complicated by intrusions of igneous rock on a large scale. Origin, sedimentary.

6. Waterbury Gneiss.— It is believed that this gneiss was originally Hartland schist, and that granitic intrusions

and quartzose veins have penetrated it to such an extent that its original appearance is largely concealed.

7. Milford Chlorite Schist.— For the most part an evenly foliated, greenish colored schist. Quartz is an important constituent in seams, lenses, and veins. Small bands of serpentine occur in the schist. Was originally a diabase or similar igneous rock.

8. Orange Phyllite.— This rock is a slate or phyllite, highly fissile, sericitic, and usually dotted with minute garnets. Toward the west it is more micaceous, in places approaching a mica schist; and is also frequently feldspathic. Quartz veins occur frequently, and lenses of quartz are almost universally found in the formation. Believed to have been originally a shale, more or less calcareous.

9. Prospect Porphyritic Gneiss.— Is light gray in color. The gneissoid appearance is produced by bands of granular quartz and feldspar interbedded with layers composed chiefly of biotite. The porphyritic mineral is usually orthoclase, white or pink in color, and varying from one-sixteenth inch to three inches in length. The rock is believed to have been a granite porphyry intruded into the Hartland schist.

10. Bristol Granite-gneiss.— Typical rock is light gray, with gneissoid structure more or less developed by the presence of layers of biotite; more schistose layers have muscovite. An evenly banded hornblende gneiss occupies part of the area. Garnet is nearly always present, and at places rises to the rank of a principal mineral. The rock was originally a mass of granite and diorite intruded into Hartland schist.

11. Collinsville Granite-gneiss.— Two types appear intermingled without order — a light gray, heavy-bedded rock, grading into massive granite; and a very dark gray to black variety, which grades by imperceptible stages into evenly banded hornblende gneiss. The rock consists of feldspar, largely orthoclase, quartz in irregular grains, and biotite. Was originally granite and diorite intruded into Hartland schist.

12. Brookfield Diorite.— Is usually massive, but shows

also gneissoid and even schistose phases. Both light and dark types are present, the former containing much quartz, and in extreme cases no dark mineral except biotite. The dark variety shows an almost complete absence of quartz, and in its place dark hornblende. It is an igneous mass intruded into the quartzite and schists of this region.

13. Danbury Granodiorite-gneiss.— The rock presents two important facies — a biotite granite, and a diorite in which hornblende becomes an important constituent and quartz is less prominent. There are gradations between the two types. It is prevailingly porphyritic, with pink or white phenocrysts of feldspar. Is igneous in origin, and was intruded prior to the time when metamorphic action converted igneous and sedimentary rocks alike into gneisses and schists.

14. Thomaston Granite-gneiss.— Rock varies in structure from an almost massive granite to a rock with distinctly schistose phases. It is of igneous origin, as shown by the fact that it often occurs as dikes, and fragments of other rocks are included in it.

15. Glastonbury Granite-gneiss.— Two types: a granitic biotite gneiss or a biotite granite, in a narrow band along the eastern border; and a darker, well foliated gneiss, with biotite, hornblende, and epidote, in the remainder of the area. Both massive and schistose phases sometimes become augen-gneiss. Believed to be of igneous origin.

16. Bolton Schist.— Is a silvery sericite schist, showing considerable variation in character, and includes gneissoid bands, as well as beds of quartzite and marble. Besides feldspar, quartz, muscovite, and sericite, the rock contains garnet, biotite, and staurolite in abundance. Origin, sedimentary.

17. Monson Granite-gneiss.— Where typically exposed, the rock is a fine-grained, dark gray, uniform biotite-hornblende gneiss, marked at short intervals by parallel seams of quartz, and with bands of biotite and hornblende. It is believed to be of igneous origin.

18. Brimfield Schist.— The typical rock is rusty, dark or purplish in color, showing great variation in the develop-

ment of schistosity. Feldspar, quartz, biotite, and garnet are the common constituents, with sillimanite and graphite in small amounts. Origin, sedimentary.

19. Eastford Granite-gneiss.— In general, a light or dark gray gneiss, fine-grained, or in places even porphyritic. The composition and texture show the rock to be of igneous origin.

20. Woodstock Quartz Schist.— It varies in character from an almost pure quartzite to a mica schist with abundant quartz grains. Origin, sedimentary.

21. Pomfret Phyllite.— Where typically developed, it is well foliated, the foliation planes being made of minute flakes of mica, which give the rock a purplish tone and silky luster. Origin, sedimentary.

22. Putnam Gneiss.— The formation is extremely variable in texture, and sometimes in composition. It consists of bands of schist, gneiss, quartzite, and igneous intrusions in great variety. In texture the rock varies from a compact, bluish black slate and quartzite, through fine black schist, to coarse, gray, quartzose schist and feldspathic gneiss. In composition the formation shows gradations from a hornblende-biotite schist, with little or no feldspar, through a quartz-biotite schist and gneiss, to a quartzite. Origin, sedimentary.

23. Plainfield Quartz Schist.— See Woodstock Quartz Schist, No. 20.

24. Sterling Granite-gneiss.— The rock is pink or gray in tone, and is made up of two distinct types: a porphyritic gneiss, with an abundance of biotite along foliation planes; and an aplite, or granite-gneiss practically free from mica. The porphyritic type is always highly gneissoid, and the phenocrysts of pink feldspar are drawn out into lenticular forms. Where phenocrysts are absent the rock shades into a normal granite, which is intermediate between the two above mentioned types. The aplitic type is probably a later intrusion than the porphyritic and normal types. Origin, igneous.

25. Willimantic Gneiss.— In general, the rock is coarse-grained, and often porphyritic in structure, usually consider-

ably crumpled and folded. There are two varieties, the light and the dark. The light variety consists of quartz, feldspar, and biotite, in the proportions of a normal granite. The dark variety contains a relatively smaller amount of feldspar and quartz, with a larger amount of biotite and some hornblende. Origin, igneous.

26. Hebron Gneiss.— Where typically developed, the rock is a fine-grained, finely foliated gneiss, with usually a relatively small amount of feldspar. As a whole, however, it has much variety of character, not only in the nature of its minerals but in their arrangement as well. It varies from granitic gneiss to highly fissile schist, and it is only when the entire area is considered that the term gneiss seems appropriate. Believed to be of sedimentary origin.

27. Scotland Schist.— It is a coarse muscovite schist. The rock practically consists of muscovite with some biotite, and occasionally garnet and quartz. The quartz generally occurs as seams and lenses an inch or less in width. Origin, sedimentary.

28. Canterbury Granite-gneiss.— The formation consists essentially of a muscovite-biotite gneiss, varying in texture from a fine, even-grained rock, to a porphyry with feldspars a quarter of an inch or so in length. Metamorphism has produced irregular wavy bands of biotite separated by flattened layers of quartz and feldspar. Origin, igneous.

29. Middletown Gneiss.— This formation is not a unit. Where least injected with amphibolite and granite, it is a fine-grained, light gray to greenish, thin-bedded gneiss. In many places its composition is very complex. Is presumably the contact zone between the Haddam Granite-gneiss and the surrounding formations.

30. Maromas Granite-gneiss.— It is in some places massive, but usually well foliated. Composition is that of a normal granite. (See Sterling Granite-gneiss, No. 24.) This rock is eruptive, and intruded into the Bolton schist.

31. Haddam Granite-gneiss.— It is a light colored, rather fine-grained, granitic aggregate of quartz and feldspar, through which are scattered small isolated flakes of

biotite. In the outcrops the rock is a moderately thick-bedded gneiss. Origin, igneous.

32. Branford Granite-gneiss.—The rock is a medium-grained granite with a banded structure, consisting very largely of white feldspar. In the feldspars are imbedded small round quartz grains, and biotite is also present in about equal amount. Small reddish garnets commonly occur, but may fail entirely. The rock has a pronounced tendency to weather, with a brownish stain on the cleavage surfaces of the feldspar. Origin, igneous.

33. Stony Creek Granite-gneiss.— See Sterling Granite-gneiss, No. 24.

34. Lyme Granite-gneiss.— See Sterling Granite-gneiss, No. 24.

35. New London Granite-gneiss.— See Sterling Granite-gneiss, No. 24.

36. Mamacoke Gneiss.— The rocks occupying the larger areas of this formation are decidedly gneissic, sometimes containing much biotite, and more rarely hornblende, and are frequently very granitic in appearance. The typical rock is uniformly medium-grained, light to dark gray in color, and consists of white feldspar and quartz, with brilliant black mica, and sometimes small amounts of hornblende and garnet. The dark minerals constitute about one-third of the rock, but the range in both directions is considerable; in one case giving rise to a biotite gneiss, in the other a granitic one. Origin, igneous.

37. Preston Gabbro-diorite.— A dark colored rock, massive, in places porphyritic, ranging in composition from gabbro, through normal diorite to quartz diorite. A deep-seated igneous mass exposed to view by erosion.

38. Amphibolite.— In nearly all cases it has a distinct gneissoid structure, and is composed in large part of porphyritic feldspar and green hornblende, with a subordinate amount of quartz.

39. See 42.

40. Sandstone.— Sedimentary rock of Triassic age, including shales, sandstones, conglomerates.

41. Basalt.—Dark colored "trap" rock of Triassic age, occurring as lava flows interbedded with sandstones.

42. Diabase.—Dark colored "trap" rock, occurring as dikes and sheets intruded into sandstone and crystalline rock. Probably all of Triassic age.

CATALOGUE SLIPS.

Connecticut. *State geological and natural history survey.*

Bulletin no. 8. Bibliography of the geology of Connecticut. By H. E. Gregory. Hartford, 1907.

123 pp., 23^{cm}.

Gregory, Herbert Ernest.

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State of Connecticut

PUBLIC DOCUMENT No. 47

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BULLETIN NO. 8

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1907

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OF THE

GEOLOGY OF CONNECTICUT

By

HERBERT ERNEST GREGORY, Ph.D.,
Professor of Geology in Yale University

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The Case, Lockwood & Brainard Company
1907

PREFACE.

During the past five years the undersigned has had occasion to examine critically the geological literature of Connecticut. The list of papers read, and the notes made during these years, are here presented, with the hope that they may be useful to students interested in the subject.

The list of titles is believed to be practically complete to January, 1906, and a few papers of more recent date have been added. Articles in the local newspapers, and descriptions in text-books have been omitted.

In preparing the notes an effort has been made wherever practicable to give the author's main conclusions, instead of describing the table of contents. This is not attempted with the larger and more general works. With the exception of a few instances, no attempt has been made to estimate the value of the various papers, and some have been included because of their historic interest. A list of geological maps, including those used as illustrations accompanying reports, follows the list of papers. The articles catalogued are numbered serially. Numbers from 500 upward are used for the maps.

Thanks are due to Mr. Freeman Ward for valuable and expert assistance in preparation of the notes, and to Miss Elfreda Cutting and Miss Lucy Bush for assistance in preparation of the Index.

The writer will be pleased to receive notice of errors in this bulletin, especially of omitted articles.

HERBERT E. GREGORY.

NEW HAVEN, April, 1907.

LIST OF PUBLICATIONS EXAMINED, TOGETHER WITH LIST OF ABBREVIATIONS USED.

A

Am. Acad. Arts Sci., Mem. Memoirs of the American Academy of Arts and Sciences.

Am. Assoc. Adv. Sci., Proc. Proceedings of the American Association for the Advancement of Science.

Am Geol. The American Geologist.

Am. Inst. Min. Eng., Trans. Transactions of the American Institute of Mining Engineers.

Am. Jour. Sci. The American Journal of Science.

Am. Min. Jour. The American Mineralogical Journal.

Am. Nat. The American Naturalist.

Am. Phil. Soc., Proc. Proceedings of the American Philosophical Society.

— — *Trans.* Transactions of the American Philosophical Society.

Assoc. Am. Geol., Trans. Transactions of the Association of American Geologists.

Atlantic Mon. The Atlantic Monthly.

B

Boston Soc. Nat. Hist., Mem. Memoirs of the Boston Society of Natural History.

— — *Proc.* Proceedings of the Boston Society of Natural History.

British Assoc. Adv. Sci., Rept. Report of the British Association for the Advancement of Science.

C

Can. Nat. The Canadian Naturalist.

Can. Rec. Sci. The Canadian Record of Science.

Census of U. S., Rept. Report of the Census of the United States.

Cincinnati Soc. Nat. Hist., Jour. Journal of the Cincinnati Society of Natural History.

Connecticut Acad. Arts Sci., Mem. Memoirs of the Connecticut Academy of Arts and Sciences.

— — *Trans.* Transactions of the Connecticut Academy of Arts and Sciences.

Connecticut Board Agric., Rept. Report of the Connecticut Board of Agriculture.

Connecticut Mag. The Connecticut Magazine.
Connecticut Quart. The Connecticut Quarterly.
Connecticut Sch. Doc. Connecticut School Document.
Connecticut State Geol. Nat. Hist. Surv., Bull. Bulletin of the Connecticut State Geological and Natural History Survey.

E

Eclectic Mag. The Eclectic Magazine of Foreign Literature, Science, and Art.
Eng. Min. Jour. Engineering and Mining Journal.

G

Geol. Mag. The Geological Magazine.
Geol. Soc. America, Bull. Bulletin of the Geological Society of America.
Geol. Soc. London, Proc. Proceedings of the Geological Society of London.
— — *Quart. Jour.* The Quarterly Journal of the Geological Society of London.
Geol. Surv. Pennsylvania (2d), Rept. Report of the Second Geological Survey of Pennsylvania.
Geol. Surv. Wisconsin. Geological Survey of Wisconsin.
Geol. Massachusetts, Final Rept. Final Report of the Geology of Massachusetts.
Geol. New Hampshire. Geology of New Hampshire.
Geol. Pennsylvania. Geology of Pennsylvania.

I

Internat. Cong. Geol., Rept. Am. Comm. International Congress of Geologists, Report of the American Committee.

J

Johns Hopkins Univ. Circ. Johns Hopkins University Circulars.
Jour. Geol. The Journal of Geology.
Jour. Phys. Chim. Journal de Physique, de Chimie, et de l'Histoire Naturelle, par J. C. de La Métherie.

L

Leonhard, Zeitsch. Zeitschrift für Mineralogie, von K. C. von Leonhard.

M

Macfarlane's Am. Geol. R. R. Guide. An American Geological Railway Guide, by James MacFarlane.

Meriden Sci. Assoc., Trans. Transactions of the Meriden Scientific Association.

Min. Mag. Jour. Min. Soc. London. The Mineralogical Magazine and Journal of the Mineralogical Society of London.

Mon. Weath. Rev. The Monthly Weather Review.

Mus. Comp. Zoöl., Bull. Bulletin of the Museum of Comparative Zoölogy, Harvard University.

N

Nat. Acad. Sci., Biog. Mem. Biographical Memoirs of the National Academy of Sciences.

— — *Mem.* Memoirs of the National Academy of Sciences.

Nat. Geog. Mon. National Geographic Monographs.

New York Acad. Sci., Ann. Annals of the New York Academy of Sciences.

— — *Trans.* Transactions of the New York Academy of Sciences.

Neues Jahrb. Neues Jahrbuch für Mineralogie, Geologie, und Palæontologie.

P

Petermann, Mittheil. Mittheilungen aus Justus Perthes' Geographischer Anstalt über wichtige neue Erforschungen auf dem Gesammtgebiete der Geographie, von A. Petermann.

Phil. Mag. The Philosophical Magazine.

Pop. Sci. Mon. The Popular Science Monthly.

S

Sch. Mines Quart. The School of Mines Quarterly.

Scient. Am. Supp. Scientific American Supplement.

Smithson. Contr. Knowl. Smithsonian Contributions to Knowledge.

— — *Report.* Annual Report of the Smithsonian Institution.

Soc. géol. France, Bull. Bulletin de la Société géologique de France.

T

Tech. Quart. The Technology Quarterly and Proceedings of the Society of Arts.

U

U. S. Dept. Agric., Bur. Soils, Rept. Field Oper. United States Department of Agriculture. Bureau of Soils. Report of the Field Operations of the Bureau of Soils.

U. S. Geol. Surv., Ann. Rept. Annual Report of the United States Geological Survey.

— — *Bull.* Bulletin of the United States Geological Survey.

— — *Geol. Atlas U. S.* Geologic Atlas of the United States Geological Survey.

— — *Min. Res. U. S.* Mineral Resources of the United States.

— — *Mon.* Monograph of the United States Geological Survey.

— — *Prof. Paper.* Professional Paper of the United States Geological Survey.

— — *Water-Supp. and Irr. Paper.* Water-Supply and Irrigation Paper.

U. S. Nat. Mus., Proc. Proceedings of the United States National Museum.

BIBLIOGRAPHY.

1. **Agassiz, J. L. R.**

On the age of the Connecticut valley sandstones.
Boston Soc. Nat. Hist., Proc., iii, 336, 337, 1850.

Exception taken to Dr. Jackson's statement that the Connecticut sandstones are of Silurian age. Evidence of fossil fishes places the formation much later in geological time.

2. **Agassiz, J. L. R.**

On Marcou's "Geology of North America."
Am. Jour. Sci., (2) xxvii, 134-137, 1859.

Defense of Marcou's good intentions and of some of his statements.

3. **Akerly, S.**

Geology of the Hudson river and vicinity. 69 pp., 1 pl., New York, 1820.

Questions Old Red Sandstone age of Connecticut river sandstone.

4. **Barbour, E. H.**

The ancient inhabitants of the Connecticut valley.
Connecticut Almanac, 37-58, 46 figs., 1889.

A popular account of the tracks and other impressions occurring in the sandstone of Connecticut and Massachusetts.

5. **Benjamin, H. W.**

Scenes in and around Granby.
Connecticut Quart., i, 139, 140, 1895.

Describes old copper mine and Newgate prison.

6. **Blake, W. P.**

Review of a portion of the geological map of the United States and British provinces by Jules Marcou.

Am. Jour. Sci., (2) xxii, 383-388, 1856.

Enumeration and correction of numerous errors made by Marcou in the above work.

7. **Blake, W. P.**

Glacial phenomena of Mill Rock near New Haven.
Science, i, 146, 147, 1883.

Rock marked by steep south slope, gentle north slope; by rounding, grooving, polishing.

8. **Bowman, H. L.**

On an occurrence of minerals at Haddam Neck, Connecticut, U. S. A.

Min. Mag. Jour. Min. Soc. London, xiii, 97-121, 4 figs., 1 pl., 1902.

Review: U. S. Geol. Surv., Min. Res. U. S. 841, 842, 1902.

Deposit is in vein of very coarse granite. The tourmalines and associated minerals occur in pockets lined with crystallized quartz and feldspar, and sometimes beryl. The following minerals are described mineralogically, chemically, crystallographically, also in regard to their optical properties: — green and pink tourmaline, albite, microcline, green and pink apatite, brown fluor, beryl, quartz, cookeite, lilac lepidolite, greenish white muscovite, and a peculiar pink fibrous variety of the same mineral. Other minerals: — green fluor, microlite, columbite.

9. **Brace, J. P.**

Observations of the minerals connected with the gneiss range of Litchfield county, Connecticut.

Am. Jour. Sci., (1) i, 351-355, 1819.

Location of the gneiss formation and its relation to the limestone, porphyritic granite or gneiss, and mica slate. Brief mention of minerals found in the region; carbonate of lime over the whole region; cyanite or sappar, especially at Harwinton and Litchfield; staurotide; quartz; petrosilex, common in Litchfield and Goshen; common opal, in Litchfield; rarely mica; schorl; feldspar; beryl; garnets; epidote, in Washington and Litchfield; tremolite, in Litchfield, Bethlehem, and Canaan; common asbestos in Washington and New Milford; augite, in Litchfield; hornblende, actinolite, steatite, chlorite, and porcelain clay, in Litchfield; graphite, in Cornwall; ores not common; red oxide of titanium, sparingly in Litchfield.

10. **Brongniart, A.**

Miscellaneous observations relating to geology, mineralogy, and some connected topics.

Am. Jour. Sci., (1) iii, 216-221, 222-226, 1821.

Mentions the serpentine of New Haven; notices the strong resemblance of the bituminous formation of Westfield, near Middletown, to that of the bituminous marl slates of the copper mines in the counties of Mansfield and Hesse in Germany; fish impressions in each are similar.

11. **Brush, G. J., and Dana, E. S.**

On a new and remarkable mineral locality at Branchville in Fairfield county, Connecticut; with a description of several new species occurring there.

Am. Jour. Sci., (3) xvi, 33-46, 114-123, 1878; xvii, 359-368, 1879; xviii, 45-50, 1879; xx, 257-284, 1880: xxix, 201-216, 1890.

Description of the physical characteristics, crystalline form, optical properties, chemical composition, and pyrognostics of various minerals

obtained from a single vein of albitic granite at Branchville. The following is a list of the minerals found: Albite, quartz, muscovite, microcline, damourite, spodumene (and its alteration products), cymatolite, apatite, microlite, columbite, garnet, tourmaline, staurolite, eosphorite, dickinsonite, triploidite, rhodochrosite, reddingite, amblygonite (hebronite), vivianite, lithiophilite, uraninite, fairfieldite, fillowite, chabazite, killinite, natrophilite, hureaulite.

12. **Burr, H. T.**

Physical geography of the Connecticut lowland.
Connecticut Sch. Doc., No. 251, 1-17, 8 figs., 1904.

The Triassic area of Connecticut is made up of sandstones deposited in a narrow estuary, lavas, and intrusive rocks. The present topography is the result of faulting and of the establishment of streams on an ancient peneplain.

13. **Chapin, A. B.**

Junction of trap and sandstone, Wallingford, Connecticut.
Am. Jour. Sci., (1) xxvii, 104-112, 8 figs., 1835.

Maps of seven trap dikes. Detailed description of branching dike, contact phenomena, included sandstone fragments, etc.

(An unusually clear and complete description of effects of contact metamorphism; remarkable for this early date. — Ed.)

14. **Chapin, J. H.**

The Hanging Hills.
Meriden Sci. Assoc., Trans., ii, 23-28, 1886.

Brief description of the occurrence of the trap ridges around Meriden. Brief review of two theories for the origin of the trap ridges: 1. Each ridge was the result of eruption through a single vent; 2. (Davis) The traps were contemporaneous flows, since reduplicated by strike faulting. The author inclines more to No. 1.

15. **Chapin, J. H.**

The trap ridges at Meriden.
Meriden Sci. Assoc., Trans., iii, 35-36, 1888.

Brief mention of "ash bed" in anterior sheet of Lamentation Mountain.

16. **Chapin, J. H.**

The topographic survey of Connecticut.
Meriden Sci. Assoc., Trans., iv, 51-57, 1890.

A description of the method used in making the topographic map of 1893.

17. **Cochrane, H. E.**

Rocks and minerals of Connecticut.
Connecticut Sch. Doc., No. 104, 1-26, 1895.

List of minerals and rocks found occurring in the towns of the state, arranged according to Shepard's Minerals and Dana's Mineralogy.

18. **Cooper, T.**

On volcanoes and volcanic substances, with a particular reference to the origin of the rocks of the floetz trap formation.

Am. Jour. Sci., (1) iv, 204-241, 242-243, 1822.

Discusses action of water on stones and earth of globe's crust; gives large number of facts concerning volcanoes and their products; proves igneous origin of floetz trap by comparison with modern lavas, etc., as disproving the Wernerian theory that the floetz trap was of aqueous origin. In this discussion the trap formations of Connecticut are used as examples.

19. **Cornish, R. H.**

Glacial scratches in vicinity of Norfolk, Connecticut.

Am. Jour. Sci., (3) xxxix, 321, 1890.

Brief statement of direction of glacial striæ in the vicinity of Norfolk; mean direction is S. 33° E.

20. **Crosby, W. O.**

Notes on the geology of the sites of the proposed dams in the valleys of the Housatonic and Ten Mile rivers.

Tech. Quart., xiii, pp. 120-127, 1900.

The Housatonic river formerly flowed through the Ten Mile river and Swamp brook, through Pawling into the Croton drainage system; its present course through the crystallines is due to the fact that it was established on Cretaceous strata sloping southeastward, and has since maintained its direction in spite of later erosion; other changes have taken place in the river system, due to Glacial deposits. The site of the proposed dam in the Housatonic valley is about one mile south of Merwinsville, and of the dam in the Ten Mile valley about one-half mile above Webatuck.

21. **Dana, E. S.**

Trap rocks of the Connecticut Valley.

Am. Jour. Sci., (3) viii, 390-392, 1874; Am. Assoc. Adv. Sci., Proc., xxiii, pt. ii, 45-47, 1874. Abstract: Neues Jahrb., 427, 1875.

Microscopical and chemical description of the Connecticut traps; closely similar to trap from Nova Scotia, New Jersey, Pennsylvania, and North Carolina; composed of pyroxene, labradorite, and magnetite, with chrysolite and apatite; chlorite is present as alteration product. Two types: anhydrous (West Rock, etc.), and hydrous (Saltonstall ridge).

(This paper is "the first important memoir in Petrography published in this country."—Ed.)

22. **Dana, E. S.**

On the occurrence of garnet with the trap of New Haven, Connecticut.

Am. Journal Sci., (3) xiv, 215-218, 1877.

Description of garnets found in the trap of East Rock and Mill Rock. Brief description of the associated minerals,— magnetite, pyroxene, opalite, and calcite. Chemical analyses and drawings.

23. **Dana, E. S., and Brush, G. J.**

On a new and remarkable mineral locality at Branchville in Fairfield county, Connecticut; with a description of several new species occurring there.

Am. Jour. Sci., (3) xvi., 33-46, 114-123, 1878; xvii, 359-368, 1879; xviii, 45-50, 1879; xx, 257-284, 1880; xxix, 201-216, 1890.

See Brush and Dana, 11.

24. **Dana, J. D.**

Origin of the grand outline features of the earth.

Am. Jour. Sci., (2) iii, 381-398, 1847.

Discussion of the general trends of coast lines, mountain ranges, and groups of islands of the globe, including peculiarities of fissures as illustrated by Percival's map of the trap ranges ("courses of fissures") of Connecticut.

25. **Dana, J. D.**

On the plan of development in the geological history of North America.

Am. Assoc. Adv. Sci., Proc., x, 1-18, 1856; Am. Jour. Sci., (2) xxii, 335-349, map, 1856.

Development of the continent of North America, starting with a V-shaped area around Hudson Bay, by the action of two systems of forces, a southeast and southwest one. The red sandstones of Connecticut indicate the water line in the Jurassic period.

26. **Dana, J. D.**

[Review of] "Illustrations of Surface Geology," by E. Hitchcock.

Am. Jour. Sci., (2) xxiv, 430-433, 1857.

Summary of a general discussion of terraces. Hitchcock speaks of a "terrace epoch," when the terraces of the Connecticut river were made by the ocean, as the result of a general submergence and a gradual re-elevation of the continent.

27. **Dana, J. D.**

[Review of] "Geology of North America," by J. Marcou.

Am. Jour. Sci., (2) xxvi, 323-334, 1858.

Exposure and criticism of numerous incorrect statements made by Marcou in the above work.

28. **Dana, J. D.**

Reply to Prof. Agassiz on Marcou's "Geology of North America."

Am. Jour. Sci., (2) xxvii, 137-140, 1859.

Criticism of Marcou's errors and unfairness.

29. **Dana, J. D.**

On the geology of the New Haven region, with especial reference to the origin of its topographic features.

Am. Jour. Sci., (2) xlix, 275, 1870.

Topographic features produced by glaciers rather than by icebergs.

30. **Dana, J. D.**

Excursion to Hanging Hills of Meriden.

History of Wallingford, by C. H. S. Davis, 53-56, 1870.

The scenery and geological features of the Meriden region are described. The Quinnipiac and the Connecticut rivers owe their altered courses to the eruption of trap; the smaller streams were affected by post-Tertiary elevation. Between Berlin and Wallingford are eight fractures from which liquid rock issued. Only a small amount of rock has been worn by glaciers from the summits of the Hanging Hills.

31. **Dana, J. D.**

On the Quaternary, or post-Tertiary, of the New Haven region.

Am. Jour. Sci., (3) i, 1-5, 125, 126, 1871.

The drift of the New Haven region was the result of glacier rather than iceberg action; the Connecticut valley glacier was but the inferior portion of the great continental glacier.

32. **Dana, J. D.**

[Review of] "Historical notes of the earthquakes of New England, 1638-1869," by W. T. Brigham.

Am. Jour. Sci., (3) i, 304, 305, 1871.

227 earthquakes recorded since 1638. Dana calls attention to the fact that volcanoes and earthquakes are not necessarily related.

33. **Dana, J. D.**

On the Connecticut river valley glacier, and other examples of the glacier movement along the valleys of New England.

Am. Jour. Sci., (3) ii, 233-243, 1871.

Great valley depressions, as the Connecticut valley, influenced the direction of the flow of the continental glacier; in such valleys the ice movement was in the general direction of the valley.

34. **Dana, J. D.**

Triassic sandstone of the Palisade ranges.

Am. Jour. Sci., (3) ii, 459, 460, 1871.

The Connecticut sandstone contains orthoclase, and the New Jersey sandstones contain albite.

35. **Dana, J. D.**

Green mountain geology. On the quartzite.

Am. Jour. Sci., (3) iii, 179-186, 250-256, 1872.

Description of the quartzite of Canaan, Connecticut, Poughquag, New York, etc., and its general relation to the Green mountain quartzite, the crystalline limestone, and metamorphic schist; at Canaan the quartzite unconformably underlies the limestone.

36. **Dana, J. D.**

The character of trap near New Haven.
Am. Jour. Sci., (3) iv, 237, 1872.

Essential identity of the New Haven trap and Palisade (New Jersey) trap; iron in them is magnetic.

37. **Dana, J. D.**

On the quartzite, limestone and associated rocks of the vicinity of Great Barrington, Berkshire county, Massachusetts.
Am. Jour. Sci., (3) iv., 362-370, 450-453, map, 1872; v, 47-53, 84-91, 1873; vi, 257-278, 1873.

Description and general relations of the mica schist, gneiss, quartzite, and limestone of Canaan, South Canaan, and Falls Village; mention of the chloritic mica slate of the New Haven region, and the Taconic slates of Salisbury and Mount Washington.

38. **Dana, J. D.**

On the geology of the New Haven Region, with special reference to the origin of some of its topographic features.
Connecticut Acad. Arts Sci., Trans., ii, 45-112, map, 1873.

Description of the main geological features of the region. Geological events previous to the Glacial period, forming of sandstone and trap areas, subsequent elevation, erosion, etc. The Glacial period — conditions and results; events of post-Glacial time; various changes in level of the area; structure of the New Haven plain.

39. **Dana, J. D.**

On the Glacial and Champlain eras in New England.
Am. Jour. Sci., (3) v, 198-211, 217-219, 1873.

Summary of the facts, theories, and conclusions concerning the Glacial history of New England.

40. **Dana, J. D.**

On staurolite crystals and Green mountain gneisses of the Silurian age.
Am. Assoc. Adv. Sci., Proc., xxii, pt. ii, 25-27, 1873; Am. Nat., vii, 658-670, 1873; Can. Nat. (new ser.), vii, 163, 1875.

Mention of staurolite crystals, associated with garnet and their occurrence in mica schist which overlies the Stockbridge limestone at Falls Village. Facts drawn from the alternation of quartzite, limestone, gneiss or mica schist, showing that all old-looking Green mountain gneisses are not pre-Silurian, and that the presence of staurolite is no evidence of a pre-Silurian age.

41. **Dana, J. D.**

On southern New England during the melting of the great glacier.
Am. Jour. Sci., (3) x, 168-183, 280-282, 353-357, 409-438, 497-508, 1875; xi, 178-180, 1876; xii, 125-128, 1876.

2

Evidence of a flood from the melting of the glacier. Origin of the stratified estuary deposits of the New Haven plain; absence of marine life from these deposits. Discovery of reindeer bones in the clay of the Quinnipiac valley, between New Haven and North Haven. Discussion of the depression of the land and amount of subsequent elevation, through evidence furnished by terraces, estuary deposits, etc., in the river valleys of southern New England, especially in the New Haven region; the Connecticut valley before the glacial flood, when it overflowed its course in several places (in Connecticut, at Meriden). Damming of streams by drift ice during the melting of the great glacier. Discharge of the flooded Mill river into the Quinnipiac, and the effect, as registered in the drift deposits of the New Haven plain.

42. **Dana, J. D.**

On the damming of the streams by drift ice during the melting of the great glacier.

Am. Jour. Sci., (3) xi, 178-180, 1876.

Discussion of former ice dams at the narrows of several Connecticut rivers; evidenced by terraces. The Thames, Connecticut, Housatonic, Westfield, Farmington rivers are considered.

43. **Dana, J. D.**

On the relations of the geology of Vermont to that of Berkshire.

Am. Jour. Sci., (3) xiv, 37-48, 132-140, 202-207, 257-264, 1877.

The geology of the limestone region of the Green mountains (including northwestern Connecticut); stratigraphical relations of the limestones, quartzite, and schists, and the abundant occurrence of iron. Conclusions as to the chronological, lithological, and orographic relations of the formations.

44. **Dana, J. D.**

On "indurated bitumen" in cavities in the trap of the Connecticut Valley. From the report on the geology of Connecticut, by Dr. J. G. Percival.

Am. Jour. Sci., (3) xvi, 130-132, 1878.

Brief discussion of the origin of the "indurated bitumen" described by Percival as occurring in the amygdaloidal trap at Farmington, New Britain, Southbury, Rocky Hill, and Hartford; "bitumen" was distilled from the bituminous shales and limestones of the Triassic. (See Russell, 250.)

45. **Dana, J. D.**

On some points in lithology.

Am. Jour. Sci., (3) xvi, 335-343, 431-440, 1878; Can. Nat., (new ser.) ix, 40-48, 80-91, 1878.

Consideration and criticism of the value of some of the distinctive characters which are generally accepted at the present time, in defining certain kinds of rocks: 1. "Older" and "younger"; 2. Foliated or not; 3. Porphyritic structure; 4. Containing quartz or not; 5. Containing "plagioclase"; 6. Rocks consisting of a triclinic feldspar and mica; 7. Hornblendic or augitic; 8. Massive or schistose; 9.

Metamorphic or eruptive. Many illustrations from Connecticut localities, including labradiorite, diorite schist, and porphyritic granite, New Haven; granite, Stony Creek; limestone, Canaan.

46. **Dana, J. D.**

[Review of] "On the physical history of the Triassic formation in New Jersey and the Connecticut valley," by I. C. Russell.

Am. Jour. Sci., (3) xvii, 328-330, 1879.

Objection to Russell's statement that the Connecticut and New Jersey Triassic areas are the opposite parts of a once continuous anticline with a thickness of sandstone of 25,000 feet. (See Russell, 249, 251, 268.)

47. **Dana, J. D.**

On the Hudson river age of the Taconic schists, and on the dependent relations of the Dutchess county and western Connecticut limestone belts.

Am. Jour. Sci., (3) xvii, 375-388, map, 1879.

The Taconic schists are of the age of the Hudson river group; the limestone belts of western Connecticut and eastern New York are but outcropping bands of the Lower Silurian limestone formation, brought to the surface by a series of flexures.

48. **Dana, J. D.**

Note on the age of the Green mountains.

Am. Jour Sci., (3) xix, 191-200, 1880.

Evidence for embracing the whole region between the Connecticut and the Hudson (and to an unascertained distance beyond) within the limits of a Green mountain synclinorium of Lower Silurian age.

49. **Dana, J. D.**

On the geological relations of the limestone belts of Westchester county, New York.

Am. Jour. Sci., (3) xx, 21-32, 194-220, 359-375, 450-456, 3 pls., 1880; xxi, 425-443, 1 pl., 1881; xxii, 103-119, 313-315, 327-335, 1881.

Description and discussion of the general geological relations of the limestone, schist, and gneiss of New York and western Connecticut, to prove that these limestones and conformably associated metamorphic rocks are of Lower Silurian age.

50. **Dana, J. D.**

Dolerite (trap) of the Triassic-Jurassic area of eastern North America.

Am. Jour. Sci., (3) xxii, 230-233, 1881.

Criticism of Dr. Hawes's method of dolerite analysis by specific gravity mixture. The recognition of anorthite and albite as constituents of West Rock trap is not warranted by the facts. (See Hawes, 128, 129, 130.)

51. **Dana, J. D.**

On the relation of the so-called kames of the Connecticut river valley to the terrace formation.

Am. Jour. Sci., (3) xxii, 451-468, 1881.

Criticism of Upham's theory of kames. Concludes that the so-called "kames" are really part of the terrace formation. (See Upham, 283.)

52. **Dana, J. D.**

The flood of the Connecticut river valley from the melting of the Quaternary glacier.

Am. Jour. Sci., (3) xxiii, 87-97, 179-202, 360-373, 1 pl, 1882; xxiv, 98-104, map, 1882.

Abridged: Connecticut Almanac, 34-52, map, 1888.

Discussion of the general condition of the Connecticut and its tributaries during the progress of the flood; the origin of the channel-way of the river; the question as to which is the normal upper terrace in any part of the valley; dimensions, velocity, and discharge of the flooded river; the bearing of the facts on the retreat of the glacier; the question as to the elevation of the land.

53. **Dana, J. D.**

Geological age of the Taconic system.

Geol. Soc. London Quart. Jour., xxxviii, 397-408, map, 1882. (Read April 5, 1882.) Abstract: Phil. Mag., xiii, 373-374, 1882. Abstract by author: Am. Jour. Sci., (3) xxiv, 291-293, 1882.

All observers describe the schists and limestones of the Taconic area as conformable. They belong to one system, and have a high eastward dip. The limestone and schist are Lower Silurian, and the schist is the younger. Chief part of schists is of Hudson river age.

54. **Dana, J. D.**

Evidence from southern New England against the iceberg theory of drift.

Am. Assoc. Adv. Sci., Proc., xxxii, 195-198, 1883; Science, ii, 390-392, 1883.

Evidence: From — 1. The scratches and groovings over the rocks; 2. The transported bowlders and other materials; 3. The facts as to the relative level of land and sea (maximum difference of 35 feet between then and now), showing that the iceberg theory of drift is unsatisfactory for southern New England.

55. **Dana, J. D.**

[Review of] "Annual report of the state geologist of New Jersey for 1882," by G. H. Cook.

Am. Jour. Sci., (3) xxv, 383-386, 1883.

Objection to Cook's hypothesis that "the various areas of the red sandstone formation east of the Appalachians, from Massachusetts to South Carolina, were once in some way connected, and perhaps those farther northeast in the British provinces." Brief statement of the origin of the Jura-Trias of eastern North America.

56. Dana, J. D.

On the western discharge of the flooded Connecticut, or that through the Farmington valley to New Haven Bay.

Am. Jour. Sci., (3) xxv, 440-448, maps, 1883. Abridged: Connecticut Almanac, 34-52, map, 1888.

Arguments showing that the waters of the flooded Connecticut, coming through the Farmington valley, reached New Haven bay through the Mill valley rather than the Quinnipiac.

57. Dana, J. D.

[Review of] "On the relations of the Triassic traps and sandstones of the eastern United States," by W. M. Davis.

Am. Jour Sci., (3) xxv, 474-475, 1883.

Criticism of Davis's view that some of the traps are intrusive and some overflow; exception taken to the "overflow theory." (See Davis, 82.)

58. Dana, J. D.

Phenomena of the Glacial and Champlain periods about the mouth of the Connecticut valley — that is, in the New Haven region.

Am. Jour. Sci., (3) xxvi, 341-361, map, 1883; xxvii, 113-130, maps (pls. i, ii), 1883.

Description and discussion of the glacial phenomena in the New Haven region, including the sand plain and kettle-holes. There were two simultaneous movements of the glacier ice, one southwest, the other southeast.

59. Dana, J. D.

On the southward ending of a great synclinal in the Taconic range.

Abstract: British Assoc. Adv. Sci., Rept. 54th meeting, 729, 730, 1884.

The Taconic range is probably of the age of the Hudson river group or Llandeilo flags; a southern portion in southwestern Massachusetts and its continuation into Salisbury, Connecticut, is a broad tray-shaped synclinal; the area south is limestone, which comes out from beneath the dwindled, flattened-out, and worn-off mountain synclinal. (See Dana, 61.)

60. Dana, J. D.

[Review of] "Preliminary paper on the terminal moraine of the second glacial epoch," by T. C. Chamberlin.

Am. Jour. Sci., (3) xxviii, 228-231, 1884.

Review of Chamberlin's paper. Discussion of the theory as applied to the Connecticut valley, where no facts have been observed which indicate a second glacial epoch.

61. **Dana, J. D.**

On the southward ending of a great synclinal in the Taconic range.

Am. Jour. Sci. (3) xxviii, 268-276, map, 1884.

Discussion of the geological relations of limestone and schist of the Mount Washington portion of the Taconic range, which extends into northwestern Connecticut. (See Dana, 59.)

62. **Dana, J. D.**

Note on the origin of bedding in so-called metamorphic rocks.

Am. Jour. Sci., (3) xxviii, 393-396, 1884.

Discussion to prove that gneiss, schist, quartzite, etc., are parts of a stratified series. The production of schistose bedding by pressure has a very limited application; field evidence supporting this view at Stony Creek, Derby, Lime Rock, Canaan.

63. **Dana, J. D.**

On the decay of quartzite, and the formation of sand, kaolin, and crystallized quartz.

Am. Jour. Sci., (3) xxviii, 448-452, 1884.

Discussion of the formation of sand, kaolin, and crystallized quartz from feldspathic quartzite; mentions kaolin deposits of Sharon and Canaan.

64. **Dana, J. D.**

The till ridge of New Haven, called Round hill.

Am. Jour. Sci., (3) xxix, 66-67, 1885.

Brief consideration of Davis's criticism as to origin of this hill, as described by Dana in a previous article. Round hill deposited by waters descending through crevice in ice; objection by Davis to this method of origin, on the ground of absence of stratification, not well taken. (See Dana, 58; Davis, 81.)

65. **Dana, J. D.**

On the Taconic rocks and stratigraphy, with a geological map of the Taconic region.

Am. Jour. Sci., (3) xxix, 205-222, 437-443, map (pl. ii), 1885.

Presentation of facts bearing on the constitution, stratigraphical relations, and distribution of Taconic rocks. Limestone is single formation overlain by schist and quartzite and underlain by quartzite and mica schist. Within the Taconic region metamorphism increases from north to south and from west to east.

66. **Dana, J. D.**

On displacement through intrusion.

Am. Jour. Sci., (3) xxx, 374-376, 1885.

Description of the wedging action of intruding material, as shown in specimens from Canaan and Lenox.

67. **Dana, J. D.**

[Review of] "Gradual variation in intensity of metamorphism," by C. S. Middlemiss.

Am. Jour. Sci., (3) xxxv, 82-83, 1888.

Abstract of Middlemiss's statements in regard to the metamorphic phenomena of India, and brief comparison with similar phenomena in New England.

68. **Dana, J. D.**

[Review of] "Subaërial decay of rocks and origin of the red color of certain formations," by I. C. Russell.

Am. Jour Sci., (3) xxxix, 317-319, 1890.

In contrast with Russell's views Dana believes that the absence of red earth in the crystallines is due to the character of the oxidation, and that the red color of the sandstones is due to changes subsequent to deposition. (See Russell, 252.)

69. **Dana, J. D.**

Archæan limestone and other rocks in Norfolk, Connecticut.

Am. Jour. Sci., (3) xxxix, 321, 1890.

Brief mention of a small area of limestone associated with hard gneiss, granite, and some hornblendic rocks, at Norfolk; limestone considered as Archæan. Brief mention of magnetite vein two and one-half miles east of Norfolk, that had been opened and worked for a time.

70. **Dana, J. D.**

Archæan axes of eastern North America.

Am. Jour. Sci., (3) xxxix, 378-383, 1890.

Division of eastern North America into ranges and troughs which were areas, for the most part, of independent geological work. Mentions a Connecticut valley trough.

71. **Dana, J. D.**

On the four Rocks of the New Haven region. 120 pp., 7 pls., maps (pls. i-iii, vi), New Haven, 1891.

Detailed description of East Rock, West Rock, Pine Rock, and Mill Rock. They are intrusions of dolerite into upturned sandstone. East Rock and West Rock are of laccolithic origin. Pine Rock and Mill Rock are trap dikes. "Mount Carmel appears to be a combination of dikes." Pp. 41-120 describe the geology along certain walks and drives about the New Haven region, including Meriden, Maltby Park, Woodbridge, the shore line from Savin Rock eastward, including excursions to Branford, Stony Creek, and the Thimble Islands, Saltonstall ridge, and the North Haven clay deposits.

72. **Dana, J. D.**

Some of the features of non-volcanic igneous ejection, as illustrated in the four "rocks" of the New Haven region — West Rock, Pine Rock, Mill Rock, East Rock.

Am. Jour. Sci., (3) xlii, 79-110, 6 pls., maps (pls. ii, iii, vi), 1891.

Detailed description, with maps, sketches, and photographs, of the four "rocks" of New Haven. Pine Rock and Mill Rock are dikes; East Rock and West Rock are intrusions of a laccolithic character. (See Dana, 71.)

73. **Dana, J. D.**

On Percival's map of the trap belts of central Connecticut, with observations on the upturning, or mountain-making disturbance, of the formation.

Am. Jour. Sci., (3) xlii, 439-447, map (pl. xvi), 1891.

Citation of the facts favoring ejection of trap after the great mountain-making event of the valley; discussion of the character of this mountain-making disturbance.

74. **Dana, J. D.**

Additional observations on the Jura-Trias traps of the New Haven region.

Am. Jour. Sci., (3) xliv, 165-169, 1892.

Description of a 5-inch trap dike at West Rock, branching from the main rock mass.

75. **Dana, J. D.**

Manual of geology, 4th ed. 1,036 pp., 1,577 figs. and maps. New York, American Book Co., 1895.

Among the subjects dealing with Connecticut are Branchville mine, 321; Thimble islands, 949; copper mines, 745; iron mines, 127; marble deposits, 524, 530, 531; Triassic, 111, 740-742, 751-755, 799-801; glacial deposits, 194, 195, 443, 956, 970, 971; structure and age of Stockbridge limestone and related rocks, 309, 527-532; Taconic system, 495-496; Triassic strata were deposited in a valley and the traps are intrusive, 798-808; fossils 750-756.

(Dana's Manual is particularly rich in references to Connecticut geology.— *Ed.*)

76. **Dana, James Dwight. (1813-1895.)**

Biography.

E. S. Dana: Am. Jour. Sci., (3) xlix, 1-28, 1895.

Beecher: Am. Geol., xvii, 1-16, 1896.

Williams: Jour. Geol., iii, 601, 1895.

Le Conte: Geol. Soc. America, Bull., vii, 461-479, 1896.

Gilman: The life of James Dwight Dana, Harper and Brothers, New York, 1899.

77. **Davis, C. H. S.**

The Catopterus gracilis.

Meriden Sci. Assoc., Trans., ii, 19-22, 1886.

Description of a fossil fish, *Catopterus gracilis,* found in the bituminous shales at Little Falls, about two miles north of Durham Center.

78. Davis, W. M.

Brief notice of observations on the Triassic trap rocks of Massachusetts, Connecticut, and New Jersey.

Am. Jour. Sci., (3) xxiv, 345-349, 1882.

Occurrence of traps in three distinct conditions: 1. Dikes; 2. Intruded sheets; 3. Overflow sheets. Discussion of origin, etc.

79. Davis, W. M.

The structural value of the trap ridges of the Connecticut valley.

Boston Soc. Nat. Hist., Proc., xxii, 116-124, 1882.

Discussion of the Triassic problem, particularly in the Connecticut valley. Connecticut strip of sandstone not greatly reduced from its original area; its dip not the result of oblique deposition, but of post-Triassic disturbance; most of the trap ridges are edges of contemporaneous overflows of lava, so may be considered as conformable members of the sedimentary series, and serve as horizons to locate reduplication of strata by (strike) faulting; the curvature, as well as the occasional reappearance of the trap ridges, is the result of folding and faulting. (See Davis, 98.)

80. Davis, W. M.

Abstract of "High river terraces of eastern Connecticut," by B. F. Koons.

Science, i, 19, 1883.

Position of several terraces depends on ice-dams that existed during the decline of the Glacial period. (See Koons, 181.)

81. Davis, W. M.

The distribution and origin of drumlins.

Am. Jour. Sci., (3) xxviii, 407-416, 1884.

The place of drumlins in a geographical classification; terminology; general description; distribution; origin — similar to that of sand-bars in a river; discusses distribution and origin of some Connecticut drumlins. (See Dana, 58,64.)

82. Davis, W. M.

On the relations of the Triassic traps and sandstones of the eastern United States.

Mus. Comp. Zoöl., Bull., vii, 249-309, 1884. Abstract: Neues Jahrb., 230-232, 1884; Science i, 430, 1883.

Description of the Triassic formation seen at various places in New Jersey, Massachusetts, and Connecticut — Beckley Station, Meriden, Wallingford, New Haven. Brief statement of former views; literature; discussion of the general relations and origin of the trap and sandstones; extrusive nature of most of the trap proved. (For complete treatment of subject, see Davis, 98.)

83. Davis, W. M.

The structure of the Triassic formation of the Connecticut valley.

U. S. Geol. Surv., 7th Ann. Rept., for 1885-86, 455-490, 1 pl., 1888. Abstract: Am. Geol., iv, 112, 113, 1889.

Discussion of the conditions of accumulation of sandstones, shales, limestones, intrusive and extrusive flows, dikes. Discussion of the structure of the formation,— general attitude, faults and their systematic arrangement, low folds. Discussion of the mechanical origin of the formation. (See Davis, 98.)

84. **Davis, W. M.**

The structure of the Triassic formation of the Connecticut valley.

Am. Jour. Sci., (3) xxxii, 342-352, 1886.

Discussion proving that the disturbance of the strata took place after the period of deposition; was not caused by overflow or intrusion of trap sheets; was not a single monoclinal tilting. The whole region has been cut by a series of strike faults. Discussion of origin of crescentic ridges, and of probable character of the disturbing force. (See Davis, 98.)

85. **Davis, W. M.**

Results of a study on the mechanical origin of the Triassic monoclinal in the Connecticut valley.

Boston Soc. Nat. Hist., Proc., xxxiii, 339-341, 1886.

Explanation of the Triassic monoclinal given in the following statement: "Whenever unconformable masses are deformed together, the structure given to the lesser, relatively superficial mass must depend in great part on the changes in the surface shape of the greater, deeper mass below." Schists and gneisses have slipped on each other because of lateral pressure. Proof: strike of surface faults corresponds with the strike of the schist beneath.

86. **Davis, W. M.**

The mechanical origin of the Triassic monoclinal in the Connecticut valley.

Am. Assoc. Adv. Sci., Proc., xxxv, pp. 224-227, 1887.

Monoclinal faulting due to slipping of underlying schists and gneisses along their vertical cleavage planes. (See Davis, 85, 98.)

87. **Davis, W. M.**

The ash bed at Meriden and its structural relations.

Meriden Sci. Assoc., Trans., iii, 23-30, 1888.

(See Davis, 98.)

88. **Davis, W. M.**

The faults in the Triassic formation near Meriden.

Mus. Comp. Zoöl., Bull., xvi, 61-87, 5 pls., 1889.

(See Davis, 98.)

89. **Davis, W. M.**

Topographic development of the Triassic formation of the Connecticut valley.

Am. Jour. Sci., (3) xxxvii, 423-434, 1889. Abstract: Pop. Sci. Mon., xxvi, 573, 1889.

Discusses mechanism of monoclinal faulting; topographic development of the Triassic belt, etc. (See Davis, 85, 86, 98.)

90. **Davis, W. M.**

Remarks on structure of fillings of fissures in trap at Meriden.

Geol. Soc. America, Bull., i, 442, 1890.

Brief mention of the fact that detrital material supplied from above takes a horizontal stratification as it settles into fissures in the trap of the quarry at Meriden. (See Davis, 98.)

91. **Davis, W. M.**

Physical geography of southern New England.

Johns Hopkins Univ. Circ., x, No. 87, 78, 79, 1891.

Chief variety of form of southern New England is found in the valleys etched beneath the general surface; the upland is a peneplain; southern New England a region of ancient deeply buried rocks, consisting of "greatly distorted and overturned schists and bedded rocks." "The present altitude of the highlands is the result of subsequent massive elevation;" the hills that lie above the peneplain are remnants of the late Cretaceous surface, and the valleys of post-Cretaceous date; the effect of glaciation and the action of currents and waves upon the shore line is described. (See Davis, 96.)

92. **Davis, W. M.**

The Triassic sandstone of the Connecticut valley.

Johns Hopkins Univ. Circ., x, No. 87, 79, 1891.

Four stages of the formation are pointed out: 1. Accumulation of sandstone and shale with sheets of lava, and at least one great intrusive sheet; 2. Post-Triassic stage of tilting and faulting; 3. Reduction of the elevated mass to a peneplain during Jurassic and Cretaceous time; 4. In Tertiary time, gentle uplifting and tilting to the south or southeast. After this period the streams cut the valleys down nearly to a new base-level. (See Davis, 96, 98.)

93. **Davis, W. M.**

The Triassic formation of Connecticut.

Geol. Soc. America, Bull., ii, 415-424, 1891.

Discussion of the structure and origin of the Triassic formation, particularly of the area around Meriden; Mount Carmel mentioned as a possible vent through which the lava of the trap sheets rose to the surface. (For complete discussion of Triassic formation, see Davis, 98.)

94. **Davis, W. M.**

The geological dates of origin of certain topographic forms on the Atlantic slope of the United States.

Geol. Soc. America, Bull., ii, 545-586, 1891. Abstract: Am. Geol., viii, 260, 1891.

Classification of topographic forms according to age or degree of development. Description of the topographic forms of the Atlantic

slope, including the resurrected pre-Triassic and the uplifted Cretaceous peneplain of southern New England. Also the Tertiary excavation in the Cretaceous peneplain.

95. **Davis, W. M.**

The lost volcanoes of Connecticut.

Pop. Sci. Mon., xl, 221-235, 1892.

Mount Carmel may be the volcanic neck or the remains of the plug in the vent through which the volcanic material of the Connecticut valley was thrown out, particularly the ash and bombs at Lamentation Mountain.

(The evidence that Mount Carmel was a volcano which furnished the Triassic lavas is unsatisfactory.— *Ed.*)

96. **Davis, W. M.**

The physical geography of Southern New England.

Nat. Geog. Mon., i, 269-304, 6 figs. New York, American Book Co., 1895.

The subject is discussed under the following heads: 1. Upland of Southern New England,— its general features, origin, peneplain, monadnocks; 2. Valleys in the upland,— slanting of peneplain, revival of rivers, depth and breadth of valleys, Connecticut valley lowland, lava ridges, distribution of population; 3. Glacial invasion,— forms of drift, geographical consequences; 4. Coast-line, depression, modification by waves and currents.

97. **Davis, W. M.**

The quarries in the lava beds at Meriden, Connecticut.

Am. Jour. Sci. (4) i, 1-13, 3 figs., 1896.

Description of the quarries in the Triassic formation at Meriden, showing the vesicular upper surface of one lava bed under the dense basal portion of a later flow, and a number of fractures dislocating the double flow. Relation of these features to the geological structure of the district. (See Davis, 98.)

98. **Davis, W. M.**

The Triassic formation of Connecticut.

U. S. Geol. Surv., 18th Ann. Rept., pt. ii, 9-192, 20 pls., 52 figs., 1898.

Detailed description and discussion of the origin and formation of the Triassic under three main heads: 1. Deposition,— the floor of the older rocks; Triassic strata; igneous rocks, intrusive and extrusive (anterior, main, and posterior sheets); vulcanism; isostasy; relation of deposition and deformation. 2. Deformation,— changes from original attitude, warps, faults. 3. Denudation,— general principles of land sculpture; cycles of denudation; initial form of monoclinal faulting; Cretaceous peneplain; Tertiary dissection of the uplifted peneplain; Glacial modifications of form and drainage; review of origin of drainage. Previous studies of the Connecticut Triassic. The extrusive nature of most of the trap formations is proved. The present arrangement of ridges is shown to be due mainly to a uniform system of faulting; and these fault lines are preserved in the topography of the region.

(This is the most important single contribution to the geology of central Connecticut, and in it is included practically all the matter

covered in the other papers by Davis, and those by Griswold and by Whittle.— *Ed.*)

99. Davis, W. M., and Griswold, L. S.

Eastern boundary of the Connecticut Triassic.

Geol. Soc. America, Bull., v, 515-530, 1894. Abstract: Am. Geol., xiii, 145, 146, 1894; Am. Jour. Sci., (3) xlvii, 136, 137, 1894.

General geological history of the region given. Special discussion of faults. Evidence showing that the entire eastern boundary of the Triassic formation in Connecticut is defined by fault lines. (See Davis, 98.)

99a. Davis, W. M., and Loper, S. W.

Two belts of fossiliferous black shale in the Triassic formation of Connecticut.

Geol. Soc. America, Bull., ii. 415-430, 1891.

General stratigraphy of the formation. Special account of fossils of the two strata of black shale. (See Loper, 189.)

100. Davis, W. M., and Whittle, C. L.

The intrusive and extrusive Triassic trap sheets of the Connecticut valley.

Mus. Comp. Zoöl., Bull., xvi, 99-138, 1 pl., 1889.

Statement of the means of distinguishing intrusions and extrusions. General features and discussions of intrusive and extrusive sheets in the following localities of Connecticut: East and West Rock, New Haven; Gaylord's mountain, Roaring brook, Cheshire; anterior at north end of Totoket; ½ mile southeast of East Meriden; north end of Higby mountain; south and west of Chauncy peak; anterior of Lamentation mountain; anterior of Cat Hole peaks; anterior of Notch mountain; anterior of Shuttle Meadow mountain; anterior of Farmington mountain: Farmington river gap; Saltonstall mountain; Totoket mountain, inside south and north brooks; Higby mountain; Lamentation mountain; Meriden city quarry; 1st and 2d ridges posterior to Saltonstall mountain; ridge near Middlefield station; falls of the Aramamit river; Highland lake; Hartford avenue and North Stanley street, New Britain; near Trinity College, Hartford. (See Davis, 98.)

101. Deane, J.

Ichnographs from the sandstone of the Connecticut valley. 61 pp., 46 pls. Boston, Little, Brown and Co., 1861.

The incomplete papers of Dr. Deane, compiled and edited by T. T. Bouvé, H. I. Bowditch, A. A. Gould, and others.

(Doubt is cast on the bird origin of the footprints, and Deane's part in the discovery of the first specimens is magnified.— *Ed.*)

102. Des Cloiseaux, A. L. O.

Optical examination of the red feldspar of the granite from Lyme, Connecticut.

Am. Jour. Sci., (3) xx, 335-336, 1880.

Brief description of the microcline from the coarse granite of the MacCurdy quarry at Lyme.

103. **Dewey, C.**

A sketch of geology and mineralogy of the western part of Massachusetts and a small part of the adjoining states. Am. Jour. Sci., (1) viii, 1-60, 240-244, map, 1824.

Description of the occurrence, general relations, and character of the mica slate, granular limestone and quartz rock found in the northwestern part of Connecticut. Mentions the following minerals: garnet, staurotide, schorl, cyanite, tremolite, nephrite, calcareous tufa, clay, some zinc mineral, also iron ores from Salisbury.

104. **Dobson, P.**

Remarks on bowlders.
Am. Jour. Sci. (1), x, 217, 218, 1826.

Description of sandstone bowlders worn smooth on one side and exhibiting scratches and furrows on the abraded part, found below as well as at the surface. "Have been worn by being suspended and carried in ice, over rocks and earth, under water." (See Dobson, 105.)

(The observations of Peter Dobson, a cotton manufacturer of Vernon, were keen, and his views of glaciation were far in advance of his time. Mr. Dobson received the enthusiastic endorsement of Murchison in the Annual Address of the Geological Society of London, 1842.— *Ed.*)

105. **Dobson, P.**

Hints on the iceberg theory of drift.
Am. Jour. Sci. (1), xlvi, 169-172, 1844.

Describes striated, subangular bowlders, which indicate work of ice,—presumably icebergs. (See Dobson, 104.)

(This letter of Mr. Dobson's was written to Prof. Hitchcock, November 15, 1837, and sent to the *American Journal of Science* in 1844.— *Ed.*)

106. **Dorsey, C. W., and Bonsteel, J. A.**

Soil survey in the Connecticut valley.
U. S. Dept. Agric., Bur. Soils, Rept. Field Oper. for 1899, 125-140, 6 pls., map, 1900.

The area described in Connecticut extends from Glastonbury to the Massachusetts line, and from the eastern crystallines to the Talcott range. Tobacco soils are described in detail under the headings: Triassic stony loam; Holyoke stony loam; Windsor sand; Hartford stony loam; Podunk fine sandy loam; Connecticut meadows; Enfield sandy loam; Suffield clay; Elmwood loam; Connecticut swamp.

107. **Eaton, G. F.**

Notes on the collection of Triassic fishes at Yale.
Am. Jour. Sci., (4) xv, 259-268, 18 figs., 1903.

The following species are described: Semiohotus fultus; S. micropterus; S. Marshi; S. tenuiceps; S. ovatus; Catopterus gracilis. Semionotus micropterus is known only from Connecticut.

108. **Eckel, E. C.**

Brown hematite deposits of eastern New York and western New England.

Eng. Min. Jour., lxxviii, 432-434, 6 figs., 1904.

Two mines occur in Salisbury. The Davis mine from top to bottom shows limonite and clay 15-20 ft.; ocher 20-40 ft.; lenses of manganese ore; "black ocher" 1-5 ft. The ore contains manganese and slight amount of phosphorus, and was originally deposited as limonite. The Ore Hill mine consists of a large body of disintegrated ore mixed with clay. The iron content runs from 35% to 50%. Manganese and iron carbonate, also phosphorus, occur. The ore originated as replacement of limestone by iron carbonate.

109. **Eggleston, J. W.**

Some glacial remains near Woodstock, Connecticut.

Am. Jour. Sci., (4) xiii, 403-408, 1902.

Description of kames, eskers, kettle-holes, and terraces of an old lake bed of which Woodstock pond is the remnant.

110. **Emerson, B. K.**

The age and cause of the gorges cut through the trap ridges by the Connecticut and its tributaries.

Am. Assoc. Adv. Sci., Proc., xxxv, 232, 1886.

" The gorges were cut by the pre-Glacial drainage, and the streams were restored to their old course by the position of their deltas.".

111. **Emerson, B. K.**

Diabase, pitchstone, and mud inclosures of the Triassic trap of New England.

Geol. Soc. America, Bull., viii, 59-86, 7 pls., 1897.

The Meriden "Ash Bed" is described in detail, including the petrography and chemistry of the pitchstone, glass and sand. The origin of the glasses and minerals is discussed, and an analysis of the basic pitchstone given.

112. **Emerson, B. K.**

Holyoke Folio, Massachusetts-Connecticut.

U. S. Geol. Surv., Geol. Atlas U. S., Folio No. 50, 1898.

Topography, general and economic geology of a strip about 2½ miles wide along the north edge of Connecticut between the meridians 73° and 72° 30′. Describes the following formations: Washington gneiss; Becket gneiss; Hoosac schist; Chester amphibolite; Sugarloaf arkose; Longmeadow sandstone; Holyoke diabase; Chicopee shale; and Glacial deposits.

113. **Emerson, B. K.**

Geology of eastern Berkshire county, Massachusetts.

U. S. Geol. Surv., Bull. No. 159, 135 pp., 9 pls., 16 figs., maps, 1899.

Geology of parts of the towns of Norfolk, Colebrook, North Canaan, and Hartland. In the North Canaan-West Norfolk area are

found: Hinsdale limestone and Washington gneiss, pre-Cambrian; hornblende schist, Becket conglomerate gneiss, Cambrian; Stockbridge limestone, Silurian. Analyses of nodule from gneiss and of pre-Cambrian limestone. Bibliography.

114. **Emerson, B. K.**

Note on corundum and a graphitic essonite from Barkhamsted, Connecticut.

Am. Jour. Sci., (4) xiv, 234-236, 1902.

Description of the corundum and a graphitic garnet rock occurring in a coarse mica schist.

115. **Emmons, E.**

Agriculture of New York, comprising an account of the classification, composition, and distribution of the soils and rocks and natural waters of the different geological formations, together with a condensed view of the climate and agricultural productions of the State.

I, 371 pp., 21 pls., 4°, Albany, 1846. (Has a good map.) Chapter on "the Taconic system" issued separately, 67 pp., 6 pls., 4°, Albany, 1844.

Stockbridge limestone and accompanying schists are described and stated to rest on Taconic slates.

(The Taconic system of Emmons along western New England and eastern New York corresponds to the Cambrian and Ordovician systems combined. Emmons believed the Taconic to be an independent system because it rests unconformably upon Primary schists and passes unconformably beneath the New York system.— *Ed.*)

(See Dana, 48, 59, 61, 65; Walcott, 286, 287.)

116. **Fippin, E. O.**

Soil survey of the Connecticut valley.

U. S. Dept. Agric., Bur. Soils, Rept. Field Oper. for 1903, 31-61, map, 1904.

The work done in 1899 was extended by the survey of 260 square miles in Massachusetts and Connecticut. The work of the two years resulted in a survey of that part of the Connecticut Triassic between Berlin and the Massachusetts line. The types of soil represented are Holyoke stony loam; Triassic stony loam; Hartford sandy loam; Connecticut meadows; Windsor sand; Chicopee gravel loam; Enfield sandy loam; Manchester sandy loam; Connecticut swamp; Norfolk coarse sandy loam; Suffield clay; Elmwood loam; Podunk fine sandy loam; Bernardston loam.

117. **Frazer, P., Jr.**

Description of microscopic sections of traps.

Am. Phil. Soc., Proc., xiv, 430, 431, 1876.

Comparison of traps from Pennsylvania and Connecticut. The fine-grained, greenish dolerites were exactly alike in both localities; coarse-grained gray rock, which in fragments seemed identical, under the microscope showed differences, the specimen from Connecticut being coarse-grained dolerite, while that from Pennsylvania was true syenite.

118. **Frazer, P., Jr.**

[Review of] "On the physical history of the Triassic formation in New Jersey and in the Connecticut valley," by I. C. Russell.

Am. Nat., xiii, 289-292, 1879.

Criticism of Russell's views regarding the Triassic formation. (See Russell, 249.)

119. **Fuller, M. L.**

Triassic rocks of the Connecticut valley as a source of water-supply.

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 110, 95-812, 8 figs., 1905.

Occurrence of waters in Triassic rocks of various types: influence of jointing and faulting on the underground waters: conditions favorable to flowing wells; water is in most instances highly mineralized, but rarely subject to pollution. Proper depth of wells.

120. **Gannett, H.**

A geographic dictionary of Connecticut.

U. S. Geol. Surv., Bull. No. 117, 67 pp., 1894.

All the names of towns, rivers, etc., given on the topographic atlas of 1893 are listed and briefly described; the area of each county is given.

121. **Gannett, H.**

Magnetic declination in the United States.

U. S. Geol. Surv., 17th Ann. Rept. for 1895-96, pt. 1, 211-428, 1896.

(See also, U. S. Coast and Geod. Surv., Rept. for 1888.)

Data for determination of secular variation based on observations at Hartford from 1810 to 1879, at New Haven from 1811 to 1885, and in less degree at other stations. The west declination of the needle in 1900 for places in Connecticut is as follows: Stamford 9° 45'; Norwalk 10° 10'; Black Rock 10° 10'; Bridgeport 9° 40'; Hartford 9° 20'; Saybrook 10° 10'; Middletown 10° 10'; Milford 9° 55'; New Haven 9° 35'; Hebron 9° 10'; Pomfret 11° 00'; Putnam 11° 10'.

122. **Gibb, G. E.**

Crystallized bodies discovered in meteoric stone.

Am. Min. Jour., i, 190, 1814.

Pyrite crystals found in Weston meteorite: prove rock not formed in the air. (See Silliman and Kingsley, 261.)

123. **Gregory, H. E.**

Connecticut. (Well and spring records.)

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 102, 127-159, 1904.

Considers briefly the underground water conditions (127) and gives tables and notes relating to wells (128-149) and springs (149-159.) The

well data include source, temperature, yield, quality (including analyses), and uses; the spring data, temperature, yield, source, use, improvements, and quality (including analyses).

124. **Gregory, H. E.**

Underground waters of eastern United States: Connecticut.

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 114, 76-81, map, 1905.

The water supply as related to the geology of the state. The limestone area, sandstone area, crystalline area, faults, drift, are the subheads.

124a. **Gregory, H. E.**

The Geology of Connecticut as related to water supply.

Connecticut Board Agric., Rept., 283-297, 1906.

Description of the sources of water supply — rivers, lakes, ground water.

124b. **Gregory, H. E., and Rice, W. N.**

Manual of Connecticut geology.

Connecticut State Geol. Nat. Hist. Surv., Bull. No. 6. 259 pp., 31 pls., 22 figs. (10 maps), 1906.

(See Rice and Gregory, 243a.)

124c. **Gregory, H. E., and Robinson, H. H.**

Preliminary geological map of Connecticut.

Connecticut State Geol. Nat. Hist. Surv., Bull. No. 7. 39 pp., 1 fig., 1907, together with a geological map of Connecticut, 1906.

A description of the geological map, also an outline of the geology of the state, history of the Connecticut surveys, and an outline of geological work done in the state by various organizations and individuals.

125. **Griswold, L. S.**

A basic dike in the Connecticut Triassic.

Mus. Comp. Zoöl., Bull. xvi, 239-242, 1893.

Description (chiefly petrographic) of a dike occurring on the outlet of Beseck lake, about a quarter of a mile west of the Air Line R.R. at Baileyville; the rock probably an augite-amphibole-fourchite.

126. **Gurlt, A.**

On a remarkable deposit of wolfram ore in the United States.

Am. Inst. Min. Eng., Trans., xxii, 236-242, 1893.

Description of the wolfram ores and their geological occurrences. The Connecticut ores, consisting of wolframite, scheelite, and wolfram ochre, occur upon a "so-called contact deposit" imbedded between crystalline limestone and gneiss in Trumbull. The wolframite crystals are pseudomorphs after scheelite. Brief history of the workings of the mine is given. (See Hobbs, 156.)

127. **Hall, J.**

Paleontology of New York, volume 3, containing descriptions and figures of the organic remains of the Lower Helderberg group and the Oriskany sandstone, 1855-59 (with volume of 120 plates), xii, 523 pp., 4°, Albany, 1859.

The introduction to this volume (1-96) includes a general discussion of the conditions of deposition and of mountain-making, with mention of formations occurring in Connecticut.

128. **Hawes, G. W.**

The trap rocks of the Connecticut valley.

Am. Jour. Sci., (3) ix, 185-192, 1875.

Demonstration, by chemical analyses, of the common source of the hydrous and anhydrous varieties of trap rock.

129. **Hawes, G. W.**

The rocks of the "chloritic formation" on the western border of the New Haven region.

Am. Jour. Sci., (3) xi, 122-126, 1876.

Proof, by chemical analysis, of the similarity between the metamorphic schists and trap rocks of the New Haven region.

130. **Hawes, G. W.**

On the mineralogical composition of the normal Mesozoic diabase upon the Atlantic border.

U. S. Nat. Mus., Proc., iv, 129-134, 1881.

Chemical analyses of these rocks show that the unaltered Mesozoic diabases are all very much alike, and are composed of augite, iron oxide, in the form of magnetic and titanic iron, and a feldspar that has been shown to be labradorite: the Triassic diabases are monotonously like those in the older formations. (See Dana, 50.)

131. **Hitchcock, C. H.**

On the so-called talcose schist of Vermont.

Am. Assoc. Adv. Sci., Proc., xiii, 321-329, 1860.

Description, both chemical and geological, of so-called talcose schist of Vermont; name a misnomer; comparatively little magnesia. Brief mention of the Connecticut schist as an extension of the Vermont area.

132. **Hitchcock, C. H.**

The relations of the geology of New Hampshire to that of the adjacent territory.

Geol. of New Hampshire, ii, 3-36, 1 pl., Concord, 1877.

Reference to the formations of the Connecticut valley, including the sandstone of Connecticut.

133. **Hitchcock, C. H.**

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, geological formations.

Macfarlane's Am. Geol. R. R. Guide, 56-66, 1879; 2d ed., rev. and enl., 1890.

List of stations on Connecticut railroads given, with character and age of rock to be seen at each place. An attempt is made to correlate the rock groups of Percival with those of other localities, thus introducing the terms Laurentian, Montalban, etc., into Connecticut geology.

134. **Hitchcock, C. H.**

North America in the ice period.

Pop. Sci. Mon., xx, 229-242, 1882.

There was an eastern American area of ice which included Connecticut, and whose center was in Labrador. Old channels of the Hudson and Connecticut rivers indicate an oscillation of level.

135. **Hitchcock, C. H.**

Geological map of United States and part of Canada.

Am. Inst. Min. Eng., Trans., xv, 465-488, map, 1886.

Discussion and description of the scheme of coloration and nomenclature, recommended by the International Geological Congress, for representing the various geological formations on a map; review of earlier maps of Maclure, Hall, Lyell, E. Hitchcock, Marcou, H. D. Rogers, Hall and Lesley, Hall and Logan, C. H. Hitchcock and Blake, C. H. Hitchcock and McGee. Brief mention of geological formations in Connecticut.

136. **Hitchcock, E.**

A sketch of the geology, mineralogy, and scenery of the regions contiguous to the river Connecticut; with a geological map and drawings of organic remains; and occasional botanical notices.

Am. Jour. Sci., (1) vi., 1-86, 201-236, map, 1823; vii, 1-30, map, 1824.

In these articles are described the "East Haven granite"; granitic veins "contemporaneous with the formation of the rock"; porphyritic granite; hornblende slate, mica slate, as in Bolton, Litchfield, etc.; chlorite slate in Milford; Primitive greenstone in West Haven and Wolcott; verd-antique in Milford; Old Red sandstone, including large areas of "Coal formation" and containing fossil bones; Secondary greenstone, its structure, composition and distribution. The "greenstone" forms beds in the peculiar rocks of the Coal formation, and both greenstones and Coal formation rest on Old Red sandstone; talus proves recent creation of earth; greenstone probably of igneous origin; coal occurs in Middletown, Chatham, Southington, Berlin, Somers, Ellington, Enfield; is in very thin seams; fish remains obtained at Westfield, and plants from Granby; alluvion; geest, the bowlders of which were deposited by a current from the northeast. Eleven mines are described, also 119 mineral and rock species. Lakes formerly existed in the Connecticut valley. Table given showing relative age of all rocks.

137. **Hitchcock, E.**

Miscellaneous notices of mineral localities, with geological remarks.

Am. Jour. Sci., (1) xiv, 215-230, 1828.

Native iron, augite, and tremolite at Canaan; iron ore at Salisbury; prehnite, greenstone, sandstone, and shale at Woodbury; petrified tree stump at Southbury. In the vicinity of Lane's mine at Monroe were found wolfram, topaz, carbonate of iron, hornblende, smoky and yellow quartz, green feldspar, brown spar, associated with tripoli, black schorl, chlorophane.

138. **Hitchcock, E.**

Report on the geology of Massachusetts, Pt. 1. Economic geology.

Am. Jour. Sci., (1) xxii, 1-70, map, 1832.

Describes the location and character of the following formations in Connecticut: mica-slate, argillaceous and flinty slate, limestone, scapolite rocks, gneiss, hornblende slate, granite, New Red sandstone, greenstone, talcose slate; states their value as building stones and soil-formers. Mentions iron ore at Salisbury, copper near Granby; soap-stone near Somers; also porcelain clay. Gives opinion that the so-called coal formation of Connecticut is the New Red sandstone or its equivalent.

139. **Hitchcock, E.**

Ornithichnology. Description of the foot-marks of birds (ornithichnites) on New Red sandstone in Massachusetts.

Am. Jour. Sci., (1) xxix, 307-340, 2 pls., 1836. Abstract: Neues Jarhb., 467-472, 1836.

General and detailed description of bird-tracks found in sandstone in various parts of Massachusetts. Comparison of birds to modern species. Theories as to the geological age of the sandstone, as to the geographical conditions at the time when the birds were alive, and as to the manner in which the foot-marks were made and preserved.

140. **Hitchcock, E.**

Bed of the Connecticut river.

Geol. Massachusetts, Final Rept., 334, 1841.

Describes flow and fall of the Connecticut River.

141. **Hitchcock, E.**

The phenomena of drift, or glacio-aqueous action in North America, between the Tertiary and Alluvial periods.

Assoc. Am. Geol., Trans., 164-221, 1843.

Discussion of the origin of drift: "Phenomena of drift are the result of the joint and alternate action of ice and water." Some of the data taken from observations in Connecticut.

(The author at this early date accepted a great deal of the glacial theory as known at the present day.—*Ed.*)

142. **Hitchcock, E.**

Description of several species of fossil plants from the New Red sandstone formation of Connecticut and Massachusetts.

Assoc. Am. Geol., Trans., 294-296, 1 pl., 1843.

Description of Coniferæ found at Woodbury and Southbury.

143. **Hitchcock, E.**

On the trap tuff, or volcanic grit of the Connecticut valley, with the bearings of its history upon the age of the trap rock and sandstone generally in that valley.

Am. Jour. Sci., (2) iv, 199-207, 2 figs., 1847. Abstract: Am. Jour. Sci., (1) xlvii, 103, 104, 1844.

Tuff near Mount Tom described in detail. Order of events: Deposition of sandstone; bedded traps produced at intervals; "principal trap ranges emerged with considerable disturbance of sandstone." General dip of sandstone due to lateral pressure.

144. **Hitchcock, E.**

An attempt to discriminate and describe the animals that made the fossil foot-prints of the United States, and especially of New England.

Am. Acad. Arts Sci., Mem., iii, 129-256, 24 pls., 1848.

Forty-seven species of animals described from their foot-prints have been found in the Connecticut valley, in Massachusetts and Connecticut, classified as follows: 12 quadrupeds; 2 annelids or molluscs; 3 of doubtful origin; 32 bipeds, mostly birds. The Connecticut localities where the remains were found are Suffield, Rocky Hill, Wethersfield cove, 2 miles south of the cove, Portland, 2 miles west of Middletown.

145. **Hitchcock, E.**

Illustrations of surface geology.

Smithson. Contr. Knowl., ix, art. iii, 155, 12 pls., 1857.

Detailed description of the terraces and beaches, particularly of the Connecticut valley; they were formed during a period of submergence of the continent when the ocean stood relatively 2,000 feet higher than its present level; drift (unmodified deposits) produced partially by glaciers, mostly by icebergs, possibly by mountain slides and earthquake waves.

146. **Hitchcock, E.**

Ichnology of New England; a report on the sandstones of the Connecticut valley, especially its fossil foot-marks. xii, 220 pp., 50 pls., including hand-colored map. Boston, 1858, published by the Commonwealth of Massachusetts.

Abstract and review: Am. Jour. Sci., (2) xxvii, 270-272, 1859.

First foot-prints found in South Hadley, 1802, spoken of as tracks of "Noah's Raven"; in 1836 tracks observed on flagging stone from Montague, and sent to Hitchcock by Deane as "foot-prints of birds." Connecticut valley sandstones above and below the traps are of different ages, the upper being Jurassic, the lower may be Triassic and Permian. Trap was deposited on sandstone. Connecticut localities from which foot-prints were obtained are Suffield, Rocky Hill, Wethersfield, Portland, Middletown, Middlefield, Durham. The question of the discovery of foot-prints is discussed, and a bibliography of 63 titles is given.

(See Deane, 101.)

147. **Hitchcock, E.**

Supplement to the ichnology of New England.
93 pp., 20 pls., edited by C. H. Hitchcock, published by Commonwealth of Massachusetts, 1865.

In this report 37 new species are described, and a catalogue is given of the specimens in the Hitchcock Ichnological Cabinet at Amherst.

148 **'Hitchcock, Edward.**

Biography.
C. H. Hitchcock: Am. Geol., xvi, 133-149, 1895.
Lesley: Nat. Acad. Sci., Biog. Mem., i, 115-134, 1877.
Pop. Sci. Mon., xlvii, 689-696, 1895.

149. **Hobbs, W. H.**

Notes on some pseudomorphs from the Taconic region.
Am. Geol., x, 44-48, 1892.

Description of tremolite pseudomorphs after salite, also pseudomorphs after feldspar, found in the northwestern part of Connecticut, mainly in Canaan and Norfolk townships.

150. **Hobbs, W. H.**

On the geological structure of the Mount Washington mass of the Taconic range.
Jour. Geol., i, 717-736, 4 figs., 2 pls., map and sections, 1893.

Evidence that schist of this vicinity is below limestone, and structure of mountain is essentially anticlinal. Schist of northern extremity is above limestone; calcareous beds alternate with the schists, which have been shown to possess marked lithological differences: probability of the beds being Ordovician, although a portion may be Cambrian. The Mount Washington series consists of four members, in order of age as follows: 1. Canaan dolomite; 2. Riga schist; 3. Egremont limestone; 4. Everett schist. Striking lithological distinctions separate the two schist horizons.

151. **Hobbs, W. H.**

The geological structure of the Housatonic valley lying east of Mount Washington.
Jour. Geol., i, 780-802, 9 figs., 3 pls., map (pl. v), 1893.

District contains same horizons as Mount Washington. Ridges are anticlinals of Riga schist produced by north-south compression. Area marked by unsymmetrical folds. A reversed fault (Housatonic fault) has complicated the stratigraphy, and resulted in production of metamorphic minerals.

152. **Hobbs, W. H.**

Differential faults.
Am. Geol., xiv, 35-37, 1894.

Discussion of a new type of fault —"differential fold fault,"—and description of one at the Housatonic river in Canaan.

153. **Hobbs, W. H.**

Mineralogical notes.

Am. Jour. Sci., (3) i, 121-128, 1895.

Description of apatite and hessonite from a pegmatite vein in Canaan.

154. **Hobbs, W. H.**

The river system of Connecticut.

Jour. Geol., ix, 469-485, 2 figs., 2 maps (pls. i, ii), 1901.

The rivers of Connecticut exhibit an orientation which corresponds closely with the directions of a fault series observed in the Pomperaug valley; the "trough lines" of streams are believed to owe their existence to faults.

155. **Hobbs, W. H.**

The Newark system of the Pomperaug valley.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, 7-160, 59 figs., 27 pls., 1901.

The Newark system of the Atlantic slope in the light of recent studies; previous work on the Newark rocks of the Pomperaug valley; areal distribution of the Newark in the Pomperaug valley, and discussion of its relation to the basement floor of crystalline rocks; petrographic and chemical description of type specimens of the region. Discussion of the elevation and tilting of the Newark beds; also of the elaborate fault system of the region,— main direction of fault lines, their expression in topographic forms, their origin, comparison with other regions, fault lines, and drainage. Discussion of the steps in the degradation and erosion of the region.

(This paper deals with the Pomperaug area of Newark rocks after the manner of treatment of the Connecticut valley area by Davis. This paper and the one by Davis (98), contain all the important facts regarding the Connecticut Triassic.— *Ed.*)

156. **Hobbs, W. H.**

The old tungsten mine at Trumbull, Connecticut.

U. S. Geol. Surv., 22d Ann. Rept., pt. ii, 7-22, 1 fig., 5 pls., 1901.

The tungsten minerals, wolframite and scheelite, are found at the contact between a crystalline limestone and hornblende gneiss; the formation of wolframite after scheelite is noticed, and the crystallographic description of the two minerals is given. The associated minerals are mica, pyrite, pyroxene, scapolite, garnet, marcasite, limonite, topaz, fluor-spar, margarodite, quartz, feldspar, apatite, sphene, ilmenite, calcite, zoisite, epidote, hornblende, chalcopyrite, malachite. The first workings of the mine were for copper, lead, and silver:

(See Gurlt, 126; Hobbs, 159.)

157. **Hobbs, W. H.**

Still rivers of western Connecticut.

Geol. Soc. America, Bull., xiii, 17-26, 3 figs., 2 pls., 1901.

The Still river tributary to the Farmington, and that to the Housatonic, owe their origin partly to geological structure of the region, and partly to a damming of the valley by Glacial drift.

158. **Hobbs, W. H.**

An instance of the action of the ice sheet upon slender projecting rock masses.

Am. Jour. Sci., (4) xiv, 399-403, 2 figs., 1 pl., 1902.

Data proving that the former peaks of Sherman hill and Castle rock, in the Pomperaug valley, were removed by glacier ice.

159. **Hobbs, W. H.**

Tungsten mining at Trumbull Connecticut.

U. S. Geol. Surv., Bull. No. 213, 98, 1903.

Tungsten deposit worked from 1898 to 1901; yield of ore 5%. (See Hobbs, 156.)

160. **Hobbs, W. H.**

Tectonic geography of southwestern New England and southeastern New York.

Geol. Soc. America, Bull., xv, 554-557; Science, xix, 527; Scient. Am., Supp., lvii, 23446, 1904.

The study of certain key areas, among them Twin lakes valley and Pomperaug valley, have demonstrated the prevalence of normal fault structures and their importance in the crustal architecture of the region described. Joints and earth lineaments are found to take the same directions. The facts discovered in the "key areas" are of wider application.

161. **Hobbs, W. H.**

Lineaments of the Atlantic border region.

Geol. Soc. America, Bull., xv, 483-506, 4 figs., 3 pls., 1904.

The direction of dominant lineaments (or rectilinear earth features), usually due to faults or joints, is determined for the region between St. Lawrence bay and Georgia. Connecticut is traversed by the Connecticut and Franconia lines N 5° E, by the northern fall line N 48° E, and by the Rias coast line, N 65° E.

162. **Hovey, E. O.**

Observations on some of the trap ridges of East Haven — Branford region.

Am. Jour. Sci., (3) xxxviii, 361-383, 1 pl., 1889. Abstract: Am. Assoc. Adv. Sci., Proc., xxxviii, 232, 233, 1890; Am. Nat., xxiv, 110, 1890.

Description of Pond rock (Saltonstall ridge), Totoket mountain, and the neighboring ridges of trap; their general geological relations to the sandstone and to each other; conclusions as to origin; Pond rock considered intrusive.

163. **Hovey, E. O.**

A relatively acid dike in the Connecticut Triassic area.

Am. Jour. Sci., (4) iii, 287-292, 3 figs., 1897.

Petrographic and chemical description of a series of dikes in a railroad cut in Fair Haven. The analysis of one dike shows it to be approximately a bostonite.

164. **Hubbard, O. P.**

Great bowlder in Woodbridge, Connecticut.
New York Acad. Sci., Trans., iv, 25, 1887.

Mention of a great basaltic bowlder (45x25x15 feet) which lies on a ridge of talcose and chlorite slate, 5 miles west of New Haven. It was brought from the Meriden hills by a glacier. (Dana.)

165. **Hulbert, E. M.**

Copper mining in Connecticut.
Connecticut Quart., iii, 23-32, 8 illus., 1897.

The various localities where copper has been found within the state are described, and an account given of their discovery and history. Data are particularly complete regarding the mines of Whigville (now Edgewood) near Bristol.

166. **Hunt, T. S.**

On some of the crystalline limestones of North America.
Am. Jour. Sci., (2) xviii, 193-200, 1854.

Description of four classes of limestone, their geological position and relation to other formations, and included minerals. The limestone of western Connecticut is described.

167. **Hunt, T. S.**

On the geognosy of the Appalachian system.
Am. Nat., v, 451-486, 1871; Am. Assoc. Adv. Sci., Proc., xx, 1-35, 1871.

Age and geological relations of the crystalline stratified rocks of North America. Separation of crystalline strata of northern New York and New England into three groups: 1. The Adirondack or Laurentide series; 2. The Green mountain series; 3. The White mountain series. Their distinctive characteristics; tracing of the groups southward; geological relations; position in time scale. Discussion of the "Taconic system." The graphitic mica schists holding garnets and cyanite, in Cornwall, Connecticut, belong to group 2; other schists and gneisses of Connecticut are mentioned as belonging to one or more of the three groups.

168. **Hunt, T. S.**

Address to the American Association for the Advancement of Science [abstract and review of] (Hunt, 167).
Am. Jour. Sci., (3) ii, 205-207, 1871.

An address on the geology of the Appalachians, and the origin of the crystalline rocks. Mentions especially the rocks of New England.

("The conclusions throughout Dr. Hunt's address are open to doubts and objections."—*Am. Jour. Sci.*)

169. **Hunt, T. S.**

Remarks on the stratification of rock masses.
Boston Soc. Nat. Hist., Proc., xvi, 237-239, 1874.

The stratiform structure in erupted rocks due to the arrangement of the elements in a flowing and imperfectly liquid material; well shown in a specimen from Groton, Connecticut, in which a large angular fragment of strongly banded micaceous gneiss is inclosed in a fine-grained eruptive granite.

170. **Hunt, T. S.**

Special report on the trap dikes and Azoic rocks of southern Pennsylvania. Pt. I. Historical introduction.

Geol. Surv. Pennsylvania (2), Rept. E, xxix, 253 pp., Harrisburg, 1878.

The state geologist of Pennsylvania asked Mr. Hunt to "collate all the known, supposed, and suspected facts of American Azoic Geology." The result is a history of pre-Silurian geology, and an attempt to reconcile divergent views. Various views regarding the Taconic rocks, Stockbridge limestone, etc., of western Connecticut are discussed without arriving at definite conclusions.

171. **Hunt, T. S.**

Geology.

Smithson. Rept., 325-345, 1882.

Review of the progress of geology for 1882. Mention of the Connecticut Triassic as described by Davis — sandstones and shales, trap rocks (dikes, intruded sheets, extrusive flows).

172. **Hunt, Thomas Sterry. (1826-1892.)**

Biography.

Frazer: Am. Geol., xi, 1-13, 1893.

Can. Rec. Sci., v, 145-149, 1892-3.

173. **Jackson, C. T.**

Observations on the age of the sandstone of the United States.

Boston Soc. Nat. Hist., Proc., iii, 335-336, 338-339, 1850.

Mention of the similarity of the sandstones of Nova Scotia, Maine, Massachusetts, Connecticut, and New Jersey. Notice that the trap comes up as beds rather than dikes, always between the strata of sandstone, never through them; amygdaloidal character noticed; the sandstone is referred to the Silurian, and is held to be related to the Lake Superior sandstone.

174. **Johnston, J.**

Notice of some spontaneous movements observed in the sandstone strata in one of the quarries at Portland, Connecticut.

Am. Assoc. Adv. Sci., Proc., viii, 283-286, 1855.

Description of special cases where the sandstone strata moved suddenly about ¼ of an inch on being partially cut through in quarrying; movement takes place only in the general direction of north and south.

(See Niles, 225.)

175. **Julien, A. A.**

On the geological action of the humus acids.

Am. Assoc. Adv. Sci., Proc., xxviii, 311-410, map, 1880.

Discussion of the decomposition taking place in rocks, including the Triassic sandstones of Connecticut, and the source of the iron oxide.

176. **Kemp, J. F.**

The great quartz vein of Lantern hill, Mystic, Connecticut, and its decomposition.

New York Acad. Sci., Trans., xv, 189, 1896.

Vein 400 feet wide, 1,200 feet long; composed almost entirely of hard, milky white quartz, which, however, is very crumbly, due to effects of faulting or crushing rather than to corroding alkaline solution. The rock contains 98-99.4% SiO.

(For a different explanation of Lantern hill, see Rice and Gregory, 243a.— Ed.)

177. **Kemp, J. F.**

Granites of southern Rhode Island and Connecticut.

Geol. Soc. America, Bull., x, 361-682, 7 pls., 1899. Abstract: Am. Geol., xxiii, 105-106, 1899; Science, ix, 140-141, 1899.

Occurrence and petrography of granites along the shore from Rhode Island to New Haven, particularly at Westerly and Stony Creek. Granites are intrusives of post-Cambrian age; pegmatites and aplites are described. Analyses of granite from Westerly, Millstone point, Stony Creek.

178. **Killebrew, J. B.**

Report on the culture and curing of tobacco in the United States.

Census of U. S., 10th Rept., iii, 583-950, 1883.

The soil of the Connecticut and Housatonic valleys is suitable for tobacco. Terraces of the Champlain period and flood-plain deposits are best adapted. Character of soil derived from porphyry, micaceous rocks, granite, chlorite slate, sandstone, and trap is discussed.

179. **Kimball, H. H.**

Ice caves and frozen wells as meteorological phenomena.

Mon. Weath. Rev., 366-371, August, 1901.

Ice deposits found in summer in ravines and gorges at Meriden, Northfield, and Salisbury.

180. **Knowlton, F. H.**

Report on fossil wood from the Newark formation of South Britain, Connecticut.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, 161-162, 1901.

Microscopical description of more or less silicified wood, of the species Araucarioxylon virginianum Knowlton, found in the Newark formations of South Britain. The Connecticut material is identical with species from Virginia and North Carolina.

181. **Koons, B. F.**

High terraces of the rivers of eastern Connecticut.

Am. Jour. Sci., (3) xxiv, 425-428, 1882.

Positions of former ice dams as indicated by the terraces on the Thames, Shetucket, Natchaug, Hope, and Willimantic rivers.

182. **Koons, B. F.**

On pot-holes on the edge of a bluff at Gurleyville, Connecticut.

Am. Jour. Sci., (3) xxv, 471, 1883.

Brief description of pot-holes on the east side of the Fenton river, four miles above its mouth.

183. **Kümmel, H. B.**

Some rivers of Connecticut.

Jour. Geol., i, 371-393, 4 figs., 1893.

Connecticut streams have all been greatly readjusted. The Housatonic has been "conformably superimposed." The lower Connecticut is a revived consequent stream. The former course of the Farmington was southward to New Haven; the Scantic and Quinnipiac have been much modified.

184. **La Métherie, J. C. de.**

Abstract of Silliman's mineralogical and geological observations on New Haven and its vicinity.

Jour. Phys. Chim., lxxv, 75-79, 1812.

(See Silliman, 260.)

185. **Lee, C. A.**

Sketch of the geology and mineralogy of Salisbury, Connecticut.

Am. Jour. Sci., (1) viii, 252-261, 1824.

The geology, mineralogy, and natural scenery of Salisbury are described. The principal rocks are mica slate, fissile and injected with quartz, forming the highest points, and granular limestone. A chasm or cave in the compact mica slate is 300x60x40 feet. The alluvial deposits contain iron ore, tree trunks, and Indian skeletons. The following minerals are reported: calcium carbonate, calcium sinter, calcium tufa, magnesium, carbonate of lime, dolomite, sulphate of alumina, 9 varieties of quartz, fetid carbonate of lime, silicious sinter, hornstone, jasper, staurotide, mica, schorl, tourmaline, feldspar, beryl, wacke, scapolite, garnet, epidote, tremolite, augite, hornblende, actinolite, talc, chlorite, argillaceous slate, potter's clay, sulphur, petroleum, graphite, 9 varieties of iron, galena, zinc, manganese, titanium.

186. **Lee, C. A.**

The moving rocks of Salisbury.

Am. Jour. Sci., (1) ix, 239-241, 1825.

Bowlders in Northeast and Little ponds are being moved shorewards by the ice; one rock moved 2½ feet from December, 1823, to February, 1825, which is less than the usual rate. (See Petros, 232.)

187. **Lindsley, H. W.**

Building stones and the quarry industry.
Census of U. S., 10th Rept., x, 126-129, 1880.

A short description is given of the Connecticut quarries and quarry regions. The brown and red sandstone quarries at Portland and elsewhere in the Connecticut valley, granite, syenite, serpentine, and verd-antique marble, are included.

188. **Loomis, I. F.**

The town of Chatham.
Connecticut Quart., v, 375-377, 1899.

The old cobalt mine opened at Great Hill in 1762, by John Stephanney; worked again in 1770, when ore was shipped to England, Holland, and China. Mine operated by Seth Hunt, 1818-1820; by C. U. Shepard, 1844; Edmund Brown, 1850. Ore is arsenical pyrites, containing 80% arsenic, 9% iron, 4½% sulphur, 4% cobalt, and a trace of bismuth.

189. **Loper, S. W.**

Fossils of the anterior and posterior shales.
Geol. Soc. America, Bull., ii, 425-430, 1891.

Comparison of fauna and flora from different localities of the anterior and posterior shales sustains the theory of the original continuity of the horizons through all the now faulted blocks of the Triassic formation. Localities explored are as follows: Durham, Bluff Head, Higby, Berlin, Southington, East Haven, North Guilford, Stevens, Westfield, South Bloomfield, North Bloomfield. Species found, as follows: *Fishes,*— Diplurus longicaudatus, Newb.; Catopterus redfieldi, Egerton; Catopterus gracilis, J. H. Redfield; Ischypterus micropterus, Newb.; Ptycholepis marshii, Newb.; Catopterus anguilliformis, W. C. Redfield; Catopterus minor, Newb.; Catopterus ornatus, Newb.; Ischypterus fultus, Agassiz; Ischypterus minutus, Newb.; Ischypterus gigas, Newb. *Plants.*— Otozamites latior, Sap.; Otozamites brevifolius, F. Br.; Loperia simpexl, Newb.; Cycadinocarpus chapini, Newb.; Equisetum (?); Pachyphyllum simile, Newb.; Pachyphyllum brevifolium, Newb.; Clathropteris platyphylla, Brong.; Baiera münsteriana, Ung.; Equisetum rogersi, Sch.; Ctenophyllum braunianum, Sch. Some undetermined species both of fishes and plants.

190. **Loughlin, G. F.**

The clays and clay industries of Connecticut.
Connecticut State Geol. Nat. Hist. Surv., Bull. No. 4, 1-121, 1905.

The important clay areas of Connecticut are the northern, in the vicinity of Hartford and Windsor, Clayton, Berlin, Quinnipiac, and Milldale. The clays are discussed under the following heads: Origin; geological history; chemistry of clays; physical properties of clays; commercial classification; composition; properties; and adaptabilities. The clay industries of Connecticut are discussed under the following heads: Prospecting; manufacture of brick; manufacture of pottery; condition of the clay industry.

191. **Lowrey, T.**

Water cement of Southington, Connecticut.
Am. Jour. Sci., (1) xiii, 382-383, 1828.

Brief description of hydraulic limestone 2½ miles east of Southington; was used in the construction of the Farmington canal.

192. **Lull, R. S.**

Fossil foot-prints of the Jura-Trias of North America.
Boston Soc. Nat. Hist., Mem., v, 461-557, 34 figs., 1904.

Reviews previous work upon fossil foot-prints, describes their geological occurrence, gives a classification and systematic description of genera, species, and higher groups.

193. **Lull, R. S.**

Fossils from the Connecticut valley Triassic.
Communicated to the author.

The following species are recognized from Connecticut:

Batrachopus deweyanus E. H.=Anisopus deweyanus E. H.; B. gracilis E. H.=A. gracilis E. H.; Anchisauripus dananus (E. H.)=Brontozoum sillimanium E. H.; A. tuberosus (E. H.)=B. validum E. H.; A. exsertus (E. H.) = B. exsertum E. H.; A. minusculus (E. H.); specimen described as Plesiornis giganteus C. H. H.; Grallator cuneatus E. H.; G. cursorius E. H.; G. formosus E. H.; G. tenuis E. H.; Anomœpus curvatus E. H.; A. gracillimus C. H. H.; A. intermedius E. H.; specimens described as Plectropterna minitans E. H. and Chimæra barratti E. H.; Corvipes lacertoideus E. H.; Eubrontes divaricatus (E. H.)=Brontozoum divaricatum E. H.; E. giganteus E. H.=B. giganteum E. H.; Otozoum caudatum C. H. H.; Otozoum moodii E. H.; Argoides isodactyletus (E. H.)=Argozoum paridigitatum E. H.=? Plesiornis æqualipes E. H.; Argoides macrodactylotus (E. H.)=Argozoum disparidigitatum E. H.; Platypterna deaniana E. H.; P. delicatula (E. H.); P. tenuis E. H.; Tarsoplectrus elegans (C. H. H.)=Plectropterna elegans C. H. H.; T. lineans (E. H.)=P. lineans E. H.; T. gracilis (E. H.)=P. gracilis E. H.; Sillimanius gracilior E. H.=Ornithopus gracilior E. H.; S. tetradactylus E. H.=O. gallinaceus E. H.; Stereopoides loripes (E. H.)=Tridentipes insignis E. H.; ? Trihamus elegans E. H.; ? T. magnus E. H.; Harpedactylus sp.; Ancyropus heteroclitus E. H.; Comptichnus sp.; Cunichnoides marsupialoideus E. H.; Exocampe ornata E. H.; Isocampe strata E. H.; Palamopus rogersianus E. H. = Macropterna vulgaris E. H.; Typopus abnormis E. H.; T. gracilis E. H.; Triænopus baileyanus E. H.=T. leptodactylus E. H.; Acanthichnus cursorius E. H.; A. cursorius var. alatus E. H.; A. cursorius var. trilineans E. H.; Conopsoides larvalis E. H.; Sagittarius alternans E. H.; Unisulcus marshi E. H.; U. minutus E. H.; Bisulcus undulatus E. H.; Trisulcus laqueatus E. H.; Cochlichnus sp.; Cunicularius retrahens E. H.; C. sp.

194. **Lyell, C.**

On the fossil foot-prints of birds and impressions of raindrops in the valley of the Connecticut.

Geol. Soc. London, Proc., iii, 793-796, 1843; Am. Jour. Sci., (1) xlv, 394-397, 1843.

The red sandstone at Rocky Hill is associated with red shale, and

capped by 20 feet of greenstone; the ripple-marked and cracked shale shows drying and shrinking during deposition; there were eruptions of trap, accompanied by upheaval and partial denudation, during the deposition of the red sandstone; impressions made in the red sandstone by some animal — undoubtedly a biped — resembling those which a bird leaves; the position of the sandstone is between the Carboniferous and Cretaceous. In the neighborhood of Durham, the author collected fishes of the genera Palæoniscus and Catopterus, but no other organic remains except fossil wood.

195. **Lyman, B. S.**

Some New Red horizons.

Am. Phil. Soc., Proc., xxxiii, 192-215, 1894. Abstract: Am. Nat., xxviii, 878-879, 1894; Jour. Geol., ii, 644, 645, 1894.

Brief review of Triassic theories. Description of Pennsylvania, Virginia, Connecticut, New Jersey, and Massachusetts areas, to show that the thickness of the formation has been underestimated (in Pennsylvania should be 27,000 feet); that the trap outcrops, both in size and extent, have been overestimated; that faults are not necessary for production of the topographic forms; that the formation may prove to be as old at least as the Permian. Most of the trap supposed to be extrusive, even the Palisades. List given of all the recorded New Red fossils arranged according to horizons.

(See critical review, by G. K. G., Jour. Geol., ii, 644-645.)

196. **Maclure, W.**

Observations on the geology of the United States, etc. (explanatory of geological map).

Am. Phil. Soc., Trans., vi, 411-428, 1809.

Adopts the Wernerian system, and gives a classification embracing all the formations. Remarks the continuity of the dolomite, speaks of cobalt at Middletown, and discusses relation of rocks of eastern United States.

197. **Maclure, W.**

Observations on the geology of the United States of North America, with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils; applied to the different states of the Union, agreeably to the accompanying geological map.

Am. Phil. Soc., Trans., (new series) i, 1-91, 2 pls., 1818; Leonhard's Zeitsch., i, 124-138, 1818.

Description of the "Primitive," "Transition," "Secondary," and "Alluvial" formations of the United States, east of the Mississippi. Some accounts of soils resulting from the decomposition of these rocks. The crystallines of Connecticut are designated as "Primitive" and the Triassic as "Old Red sandstone."

198. **Marcou, J.**

Geological map of the United States, and the British

provinces in North America (with explanatory texts and geological sections). 92 pp., 8 pls., Boston, 1853.

Facts regarding the Paleozoic and Secondary rocks of Connecticut are based on the work of Hitchcock and Percival. The sandstone is considered the equivalent of the Keuper of the European Trias; the trap is like that in Auvergne and in Ireland. Fossils of ganoid fish, and foot-prints of birds are found. The Green Mountain system, the "meridional system," extends through Litchfield and Fairfield counties, and terminates near Bridgeport; the Allegheny system is found east of New Haven. The sandstone and traps are of the same age as the copper-bearing rocks of Lake Superior. The geological divisions used are those of M. de Verneuil, including Murchison's grouping of the Paleozoic.

199. **Marcou, J.**

Resumé explicatif d'une carte géologique des États-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique, et une planche de fossiles.

Soc. géol. France, Bull., (2) xii, 813-936, map, pl., 1854-55. Abstract: Petermann, Mittheil, i, 149-159, map, 1855. Reviewed and errors enumerated: Am. Jour. Sci., (2) xvii, 198-206, 1854.

Between Carboniferous and Jurassic is a series of red sandstones and shales containing few fossils; age of these deposits not Old Red sandstone as stated by some geologists, nor Oölite nor Lias as contended by James Hall. The New Red sandstone of United States divided into four series, of which Connecticut rocks are the highest. 49 species of fossil foot-prints have been described, also three ganoids. Cupriferous trap rock, contemporaneous with the sandstones, broke through fissures, lifted and metamorphosed the sandstones, and spread out in places like lava flows.

200. **Marcou, J.**

Geology of North America, with two reports on the prairies of Arkansas and Texas, the Rocky mountains of New Mexico, and the Sierra Nevada of California. 144 pp., 7 pls., 3 maps, 4°, Zurich, 1858.

Connecticut valley contains New Red sandstone; crystalline and metamorphic rocks underlie the remainder of the state. Litchfield and Fairfield are parts of the Green mountain system. "Alleghenian dislocations continue into Connecticut to the eastward of New Haven." The report contains chapters on classification of mountains, progress and discoveries of geology of North America, and bibliography of maps and memoirs.

(This report is not considered trustworthy, and was severely criticised at the time of its appearance by Hall, Whitney, Blake, Dana, and others.— *Ed.*)

201. **Markham, F. G.**

Volcanic and seismic disturbances in southern Connecticut.

Connecticut Mag., ix, 68-74, 5 figs., 1905.

Deals in a popular way with the well-known evidences of volcanic activity in the New Haven and Meriden regions, and with the "Moodus noises," which the author ascribes to explosions of steam.

202. **Marsh, O. C.**

Notice of new American Dinosauria.

Am. Jour. Sci., (3) xxxvii, 331-336, 5 figs., 1889.

Description of Anchisaurus major, sp. nov., a small carnivorous dinosaur found near Manchester, in 1884.

203. **Marsh, O. C.**

Notice of new vertebrate fossils.

Am. Jour. Sci., (3) xlii, 265-269, 1891.

Announces discovery and gives description of Ammosaurus, gen. nov., and Anchisaurus colurus, sp. nov., from Manchester.

204. **Marsh, O. C.**

Notes on Triassic Dinosauria.

Am. Jour. Sci., (3) xliii, 543-546, 3 pls., 1892.

Description of parts of Anchisaurus solus and A. colurus, and a discussion of their affinities.

205. **Marsh, O. C.**

Restoration of Anchisaurus.

Am. Jour. Sci., (3) xlv, 169-170, 1 pl., 1893.

The skeleton of the dinosaur found at Manchester was sufficiently complete to permit of restoration, and shows a slender, delicate dinosaur, which left foot-prints like the so-called "bird-tracks." No tracks of true birds are known in this horizon.

206. **Marsh, O. C.**

The Dinosaurs of North America.

U. S. Geol. Surv., 16th Ann. Rept., pt. i, 135-244, 65 pls., 66 figs., 1896.

Describes Anchisaurus colurus, Anchisaurus solus, Ammosaurus major, from Manchester. Ammosaurus major was previously described as Anchisaurus major.

207. **Marsh, O. C.**

A new belodont reptile (Stegomus) from the Connecticut river sandstone.

Am. Jour. Sci., (4) ii, 59-62, 3 figs., 1 pl., 1896.

Announces discovery of, and describes remains of, Stegomus arcuatus from New Haven.

208. **Marsh, Othniel Charles (1831-1899).**

Biography.

Beecher: Am. Geol., xxiv, 135-137, 1899.

Beecher: Am Jour. Sci., (4) vii, 403-428, 1899.

Bidwell: Eclectic Mag., 501, 502, 1878.

Grinnell: Pop. Sci. Mon., 612-617, 1878.

Woodward: Geol. Mag., (new ser.) vi, 237-240, 1899.

209. **Mather, W. W.**

Illustrations of a section through a part of Connecticut, from Killingly to Haddam on the Connecticut river.

Am. Jour. Sci., (1) xxi, 94-97, 1832.

Description and general relations of the following: granular feldspar rock and its passage into kaolin; granular quartz rock; gneiss in thick strata; contorted gneiss; gneiss traversed with veins of granite; mica slate; syenitic and hornblende rocks.

210. **Mather, W. W.**

A geological map of New London and Windham counties.

Am. Jour. Sci., (1) xxiii, 404, 1833.

Notice of map based on geological data of Mather to be published by William Lester, Jr.

211. **Mather, W. W.**

Sketch of the geology and mineralogy of New London and Windham counties in Connecticut. 36 pp., map, Norwich, 1834.

A detailed study of the geology of New London and Windham counties. The formations recognized are: 1. Gneiss; 2. hornblende slate; 3. mica slate; 4. granular feldspar; 5. granular quartz; 6. sienite; 7. granite; 8. limestone; 9. tertiary; 10. diluvial; 11. alluvial. Each of these groups is discussed under the following heads: (a) Chemical and external character; (b) range and extent; (c) elevation and general character of hills; (d) inclination and thickness of the rocks and veins; (e) water and springs; (f) agricultural character; (g) mineral contents; (h) application to useful purposes. Primitive and Tertiary formations are present, but no Secondary.

212. **Mather, W. W.**

Fossil fishes in Connecticut sandstone.

Neues Jahrb., 531-532, 1834.

Specimens of fish turned to bituminous coal, but with scales perfectly preserved, are found twenty miles from New Haven; they occur in bituminous shale, "red marl," and sandstone.

213. **Mather, W. W.**

Geology of New York, Part I (first report on southeastern district). xxxvii + 671 pp., 46 pls., 4°, Albany, 1843.

Glacial striæ and till are noted as occurring in Connecticut, and the origin of the drift deposits is discussed. The traps and sandstone of Connecticut and New York are of the same age; the dip of the sandstone is due to the original deposition by equatorial and polar currents. Identical Cambro-Silurian metamorphic rocks occur in western Connecticut and eastern New York.

214. **Mather, William Williams. (1804-1859.)**

Biography.

Am. Jour. Sci., (2) xxvii, 452, 1859.

215. **Matthew, W. D.**

Monazite and orthoclase, from South Lyme, Connecticut. Sch. Mines Quart., xvi, 231-233, 1895.

Detailed description of a large crystal of monazite.

216. **Mease, J.**

A geological account of the United States, comprehending a short description of their animal, vegetable, and mineral productions, antiquities, and curiosities. iii + 496 + xiv pp., Philadelphia, 1807.

The geological portion comprises 55 pages, 25 of which are devoted to a catalogue of minerals.

Contains exaggerated descriptions of Connecticut scenery.

217. **Merrill, G. P.**

Report on building stone of the United States and statistics of quarry industry for 1880.

Census of U. S., 10th Rept., x, 15-29, 1880.

Description of microscopic structure and mineral composition of some of the more common kinds of building stones. The Connecticut specimens described are hornblende-biotite gneiss from Middletown and sandstone from Portland.

218. **Merrill, G. P.**

The collection of building and ornamental stones in the United States National Museum.

Smithson. Rept., pt. ii, 277-648, 9 pls., 1886.

General description of the minerals of building stones; physical and chemical properties of rocks; classification of rocks; quarrying; weathering and selection of building stones. Rocks described as occurring in Connecticut are serpentine, limestone, dolomite, marble, granite, diabase, sandstone.

219. **Miller, S. A.**

North American Mesozoic and Cenozoic geology and paleontology.

Cincinnati Soc. Nat. Hist., Jour., ii, 140-161, 223-244, 1879; iii, 9-32, 79-118, 165-202, 245-288, 1880; iv, 3-46, 93-144, 183-234, 1881; also issued separately. 338 pp. Cincinnati, 1881.

Contains a compilation of data regarding composition, structure, origin, and fossil contents of the Triassic rocks of Connecticut.

220. **Newberry, J. S.**

Report on building stones of the United States, and statistics of the quarry industry.

Census of U. S., 10th Rept., x, 318-324, 1884.

Limestone of Greenwich mentioned as building stone (was used in the construction of a portion of the wall in Central Park). Thomaston granite well adapted to monumental work; Millstone point granite, fine, dark gray; that of Leete Island, reddish gray, rather coarse-grained

gneiss; that of Stony Creek, pale red in color, medium grain, a strong, compact, handsome stone. Short description also of granite at Winnepauk, Norwalk, and red granite at Lyme, also that at Niantic. Marble of Canaan is mentioned.

221. **Newberry, J. S.**

Fossil fishes and fossil plants of the Triassic rocks of New Jersey and the Connecticut valley.

U. S. Geol. Surv., Mon. xiv, 122 pp., 26 pls., 1888. Abstracts: New York Acad. Sci., Trans., vi, 124, 128, 1887; Am. Jour. Sci., (3) xxxviii, 77-78, 1889; Am. Nat., xxii, 639, 1888; Am. Geol., iv, 187-188, 1889; Pop. Sci. Mon., xxxvi, 562-563, 1889.

Short sketch of the geological relations of the Triassic rocks of New Jersey and the Connecticut valley. Description of the following fossil fishes found in Connecticut: Ischypterus ovatus, W. C. R.; Ischypterus micropterus, n. sp.; Ischypterus tenuiceps, Ag. sp.; Ischypterus fultus, Ag. sp.; Ischypterus parvus, W. C. R. (MS); Ischypterus latus, J. H. R.; Ischypterus minutus, n. sp.; Catopterus redfieldi, Egerton; Catopterus gracilis, J. H. R.; Catopterus minor, n. sp.; Catopterus anguilliformis, W. C. R.; Catopterus parvulus, W. C. R.; Ptycholepis Marshi., Newb.; Diplurus longicaudatus, Newb. Description of the following fossil plants found in Connecticut; Dendrophycus Triassicus, n. sp.; Baiera münsteriana, Ung.; Schizoneura planicostata, Rogers sp.; Pachyphyllum simile, n. sp.; Pachyphyllum brevifolium, n. sp.; Otozamites latior, Saporta; Cheirolepis münsteri, Schimper; Otozamites brevifolius F. Br.; Cycadinocarpus chapini Newb.; Loperia simplex, n. sp.; Clathropteris platyphylla Brong.

222. **Newberry, John Strong. (1822-1892.)**

Biography.

Kemp: Geol. Soc. America, Bull., iv, 393-409, 1892.

Kemp: Sch. Mines Quart., 94-111, Jan., 1893.

Stevenson: Am. Geol., xii, 1-26, 1893.

223. **[Newell, F. H.] U. S. Geological Survey.**

The Connecticut river.

U. S. Geol. Surv., 14th Ann. Rept., pt. ii, 140-146, 1893.

Tables are given showing discharge, rainfall, run-off at Hartford for years 1871-1885; based on observations made by United States Army Corps of Engineers.

224. **[Newell, F. H.] U. S. Geological Survey.**

Connecticut river: A study of the discharge and run-off of the river at Holyoke, Massachusetts, 1880-1895.

U. S. Geol. Surv., Bull. No. 140, 37-41, 1896.

(This is to be compared with the report on the Connecticut river at Hartford, 223.—*Ed.*)

225. **Niles, W. H.**

The geological agency of lateral pressure exhibited by certain movements of rocks.

Boston Soc. Nat. Hist., Proc., xviii, 272-284, 1876. Abstract: Am. Nat., x, 127, 1876.

Evidence obtained from various quarries showing that rocks are in a state of tension or compression. Shown by bulgings, crushings, and explosions when rock is removed from the quarries. Due to lateral pressure occasioned by the contraction of the globe. A general phenomenon. Among other localities observed were those of Waterford and Groton. (See Johnston, 174.)

226. **Norton, H.**

Glacier scratches in Goshen, in northern Connecticut. Am. Jour. Sci., (3) xxii, 322, 1881.

Citation of observations of location and direction of five glacial striae in Goshen, Connecticut, as follows: S41°E; S77°E; S38°E; S22¾°E; S58°E.

227. **Peet, C. E.**

Glacial and post-Glacial history of the Hudson and Champlain valleys.

Jour. Geol., xii, 415-469, 617-660, 27 maps and figs., 1904.

The relation of the Hudson water body to that of the Connecticut valley is briefly discussed.

228. **Percival, J. G.**

Notice of the locality of sulphate of barytes, from which a specimen was analyzed by Mr. G. T. Bowen, and of various other mineral localities in Berlin, Connecticut.

Am. Jour. Sci., (1) v, 42-45, map, 1882.

The sulphate of barytes is found in a vein in a ridge of greenstone within the red sandstone formation, about one-half mile west of Kensington meeting house, in Berlin. Mentions a coal mine (in greenstone only), lead mine, pyrites, carbonate of lime, quartz, chalcedony, agate, porous greenstone containing zeolites and chlorite crystals.

229. **Percival, J. G.**

Report on the geology of the state of Connecticut. 486 pp., with map, published under the direction of the Commissioners appointed by the State, 1842.

The geology of Connecticut is discussed under the following heads: Rocks, 10-452; unconsolidated materials, 453-467; soils, 467-470; economic results, 470-475; physical geography, 475-486. The rocks are grouped as Primary system, 11-298, divided into the western Primary system with 16 rock formations, and the eastern Primary system with 5 formations and numerous subdivisions; trap rocks, 299-426; the Secondary rocks, 426-452. The rocks and formations are described in detail, as regards their "mineral composition, structure, and physical character." The characters of the unstratified "Diluvium" and the stratified "Alluvium" are described at many localities.

(Percival's report is a remarkable piece of work. The difficulties under which it was undertaken, and the care with which it was done are explained in the bulletin accompanying the Preliminary Geological Map of Connecticut. The rock types and localities are described accurately,

the igneous origin of the traps is stated, and the fact of transportation of bowlders and the direction of their course is noted. The author described what he saw, and the book is a mass of geological detail. With this abundance of facts, however, there is an absence of generalizations or of an attempt to interpret the phenomena observed, and the report is therefore of little value to the reader who wishes to understand the geological history of Connecticut.— *Ed.*)

230. Percival, James Gates. (1795-1856.)

Biography.

Shepard: Atlantic Mon., iv, 59-73, 1859.

Ward: Life and Letters of James Gates Percival. 579 pp., 1866.

Pettee: Meriden Sci. Assoc., Trans., iv, 22-28, 1890.

Cogswell: Percival and his friends. Am. Jour. Sci., (2) xxii, 150-151, 1856.

Geol. Surv. Wisconsin, preface, 1856.

231. Perry, J. B.

Hints toward the post-Tertiary history of New England from personal study of rocks, with strictures on Dana's "Geology of the New Haven region."

Boston Soc. Nat. Hist., Proc., xv, 48-148, 1873.

Discussion of the non-adaptability of the iceberg theory to account for all the drift phenomena. Detailed treatment of the glacier theory and its general application to the post-Tertiary history of New England. Discussion of the marl and peat periods of post-Pliocene time. Criticism from time to time of Prof. Dana's article, "Geology of the New Haven Region."

232. Petros (C. A. Lee).

The moving rocks of Salisbury.

Am. Jour. Sci., (1) v, 34-36, map, 1822.

Northeast pond and Little pond, now separated by a narrow strip of limestone bowlders, were formerly one water body. Carrying of rocks shoreward by the ice has built this barrier. Between September, 1819, and February, 1821, a rock weighing forty tons was moved shoreward 3 rods, 2 links, leaving a trench behind.

(This is one of the first quantitative statements of the importance of lake ice in transporting material.— *Ed.*)

233. Pierce, J.

Chalybeate spring at Litchfield.

Am. Jour. Sci., (1) iii, 235, 236, 1821.

An account of a "copious and perennial spring issuing from an extensive bed of sulphuret of iron," situated on the eastern side of Mount Prospect; exhibits in its course much oxide of iron, ochre, and a white deposit.

234. Porter, T. D.

Floetz trap formation in Connecticut and Massachusetts.

Am. Jour. Sci., (1) iv., 241-242, 1822.

Brief description of the trap formation in New Haven and vicinity, mentioning their inclusions: zeolites, quartz, prehnite, etc. Slight difference between East and West Rocks and those in the region of East Haven; i. e., no regular jointed structure in latter.

235. **Putnam, B. T.**

Notes on samples of iron ore collected in Connecticut. Census of the U. S., 10th Rept., xv, 83-87, map, 1886.

Magnetic ore not found in the state in sufficient quantities to pay for mining; specular hematite is almost unknown; spathic ore exists in the vicinity of Roxbury, but is not mined; limonite the only ore mined. Description of the Kent mine, the Chatfield mine near Salisbury, the Brookpit or Ore Hill mine, the Porter mine at Lakeville, the Davis or Forbes mine north of Lakeville, and the Chapin mine west of Chapinville. Map showing location of iron mines accompanies these notes; sketch of the Chatfield mine.

236. **Pynchon, W. H. C.**

The ancient lavas of Connecticut.

Connecticut Quart., ii, 309-319, 17 reproductions from photographs, 1896.

Well illustrated, popular account of the trap ridges from Tariffville to New Haven.

237. **Pynchon, W. H. C.**

Some common evidences of glacial action in Connecticut.

Connecticut Quart., iv, 294-302, 10 illus., 1898.

A popular article on glacial action with illustrations taken from Connecticut. Views show striated rock, till, perched bowlder, sand plain, etc.

238. **Pynchon, W. H. C.**

Iron mining in Connecticut.

Connecticut Quart., v.—I. Ores and ore beds, 20-26, 4 illus; II. Smelting, 232-238, 8 illus.; III. Historical sketch, 277-285, 9 illus.; 1899.

An account of all the mines within the state. Character of the ores, methods of mining and smelting. An interesting description of the great importance of the industry during the revolutionary period, its decline and present condition. The Salisbury-Canaan region, with its mines, is described and illustrated in detail.

239. **Pynchon, W. H. C.**

Drilled wells of the Triassic area of the Connecticut valley.

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 110, pp. 65-94, with sketch map and section, 1905.

A sketch of the principal geological features of the area, followed by descriptions of a considerable number of wells, in which several points of interest are emphasized; the high percentage of mineral matter present in all the water, the general absence of flowing wells.

240. **Rafter, G. W.**

Sewage irrigation.

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 22, 89 pp., 1899.

Sewage conditions at Bristol, Danbury, Lake Wauramaug, Litchfield, Meriden, and Waterbury; gives population, filterage, and drainage as found in these places.

241. **Rice, W. N.**

On the trap and sandstone in the gorge of the Farmington river at Tariffville, Connecticut.

Am. Jour. Sci., (3) xxxii, 430-433, 1886.

Description of the relations existing between the trap and sandstone in the gorge, proving that the lower sheet of trap is contemporaneous.

242. **Rice, W. N.**

First biennial report of the commissioners of the State Geological and Natural History Survey. 18 pp., Hartford, Connecticut, 1904.

The act establishing the state geological and natural history survey was passed June 3d, 1903. The commissioners met on June 25th, 1903, and appointed William North Rice superintendent. The work undertaken during the first year includes a manual of geology, a geological map, and an investigation of the clays.

243. **Rice, W. N.**

The physical geography and geology of Connecticut.

Connecticut Board of Agric., Rept., 74-112, 2 maps, 1904.

A general sketch of the geology and geography of Connecticut, showing three physiographic divisions. The method of formation of the different rocks is outlined, as is also the geological history.

243a. **Rice, W. N., and Gregory, H. E.**

Manual of Connecticut geology.

Connecticut State Geol. Nat. Hist. Surv., Bull. No. 6, 259 pp., 31 pls., 22 figs., 1906.

This report is divided into four parts: 1. Geography of Connecticut as related to geological structure and history; 2. The Crystalline Rocks, including a discussion of their composition and structure and also a description of the different rock formations of the western and eastern Highlands; 3. The Triassic, including sedimentary rocks and the traps; 4. Glacial Geology. The manual is "an outline of what is known in regard to the geological structure and history of Connecticut."

244. **Ries, H.**

The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut.

U. S. Geo. Surv., 17th Ann. Rept., pt. iii (cont.), 795-811, 1896.

Description of localities and character of the limestones, including the Stockbridge limestone, quarried at Canaan, and used for making lime. Chemical analyses are given.

245. **Ries, H.**

Clays of the United States, east of the Mississippi river.
U. S. Geol. Surv., Prof. Paper No. 11, 1-287, 1903.

Clays of Connecticut, and analysis of kaolin found at West Cornwall; clay-working industry around Berlin, Hartford, New Haven, and Middletown; value of clay products in the State.

245a. **Robinson, H. H., and Gregory, H. E.**

Preliminary geological map of Connecticut.
Connecticut State Geol. Nat. Hist. Surv., Bull. No. 7, 39 pp., 1 fig., together with a geological map, 1906.

(See Gregory and Robinson, 124c.)

246. **Rogers, H. D.**

Nature of the dip of the Triassic of the eastern United States.
Am. Jour. Sci., (1) xliii, 170-171, 1842; Assoc. Am. Geol., Trans., 63-64, 1843.

Brief statement to the effect that the dip of the Connecticut sandstone is the result of oblique deposition. This objected to by Lyell and Silliman. The latter mentions upheaval as the cause.

247. **Rogers, H. D.**

Cause of crescent-formed dikes of trap in New Jersey and Connecticut.
Am. Jour. Sci., (1) xlv, 334, 1843.

Brief statement that the crescent form of the trap dikes is in some manner connected with the dip of the stratified rocks which they traverse.

248. **Rogers, H. D.**

Sketch of the geology of the United States.
Geol. Pennsylvania, ii, 741-775, Philadelphia, 1858.

The geology of New England and of the Connecticut valley is briefly compared with that of other regions.

249. **Russell, I. C.**

On the physical history of the Triassic formation in New Jersey and in the Connecticut valley.
New York Acad. Sci., Ann., i, 220-254, 1879.

Description of the Triassic areas of eastern United States, particularly those in New Jersey and Connecticut. Conclusions: 1. The Triassic beds are the borders of one great estuary deposit, the central part of which was slowly upheaved and then removed by denudation; 2. The outbursts of trap must have occurred after the sedimentary beds had been upheaved and eroded; 3. The detached areas of Triassic rock occurring along the Atlantic border from New England to North Carolina seem fragments of one great estuary formation, now broken up and separated through the agency of upheaval and denudation. (See Dana, 46.)

250. Russell, I. C.

On the occurrence of a solid hydrocarbon in the eruptive rocks of New Jersey.

Am. Jour. Sci., (3) xvi, 112-114, 1878.

Description of brilliant jet black carbonaceous mineral resembling albertite, in the cavities of amygdaloid trap; comparison with a similar mineral described by Percival as occurring in the trap areas of Connecticut. (See Dana, 44.)

251. Russell, I. C.

On the former extent of the Triassic formation in the United States.

Am. Nat., xiv, 703-712, 1880.

The detached areas of Triassic rocks, from South Carolina northward to Connecticut and Massachusetts, are portions of the one great estuary deposit, which has been broken up into separate areas by upheaval and denudation.

252. Russell, I. C.

Subaërial decay of rocks, and origin of red color of certain formations.

U. S. Geol. Surv., Bull. No. 52, 1-56, 5 pls., 1889.

Red color of Connecticut sandstones due to coating of quartz grains with ferric oxide in residual clay. Sandstones were "formed from debris of lands that had been long exposed to the action of a warm, moist atmosphere." (See Dana, 68.)

253. Russell, I. C.

The Newark system.

U. S. Geol. Surv., Bull. No. 85, 340 pp., 4 figs., 13 pls., 1892.

Summarizes existing knowledge regarding Triassic rocks (Newark System) of Connecticut and other eastern states. The Connecticut valley and Southbury areas are mapped and described. Rocks were deposited in tide-swept estuaries during a period of mild climate. A list of fossils is given. Igneous rocks associated with sediments are dikes, intrusive sheets, and lava flows. The structure of the area is monoclinal, and is controlled by "faults of all degrees of displacement up to many hundreds of feet," as shown by Davis. "Each of the Newark areas [along the Atlantic border] was originally much larger than now, and there is a strong probability that all the areas between Massachusetts and South Carolina were originally united." Newark system is in upper part Jurassic and lower part Triassic. The "Index to the literature of the Newark system" (133-339) is very complete.

254. Seeley, L.

Garnet Rock.

Am. Jour. Sci., (1) iii, 241-242, 1821.

A rock in Redding abundantly studded with garnets of various sizes and qualities.

255. **Shaler, N. S.**

Fluviatile swamps of New England.

Am. Jour. Sci., (3) xxxiii, 210-221, 1887. Abstract: Pop. Sci. Mon., xxxiii, 142, 143, 1887.

Discussion of differences between rivers flowing from north to south, and those flowing from south to north. The former have terraces and no swamps; the latter have no terraces and numerous swamps; caused probably by a depression of land at south, thus lowering the grade of north-flowing streams.

(No reference to individual Connecticut streams.— *Ed.*)

256. **Sheldon, J. M. A.**

Concretions from the Champlain clays of the Connecticut valley. 42 pp., 123 figs. of nearly natural size, illustrating the "Stone-Arms Collection." A bibliography relating to works on concretions is also given. Boston, 1900.

Concretions are described from the Connecticut valley, including Hartford and Windsor, Connecticut; they are formed in the clay by robbing the clay of its lime. Analysis shows concretions to be about one-half clay or sand. The process by which concretions are formed is discussed, also the factors which determine their shape.

257. **Shepard, C. U.**

Notice of a mine of spathic iron (steel ore) of New Milford, and of iron works of Salisbury, Connecticut.

Am. Jour. Sci., (1) xix, 311-326, 1831.

History of the New Milford mine, which at first was worked for silver; geology of the region — the iron and quartz exist together as a seam 6-8 feet wide in the gneiss; description of the ore; Salisbury iron works — occurrence of the ore, theory of its origin, history of the opening of the ore, annual yield, etc.

258. **Shepard, C. U.**

A report on the geological survey of Connecticut, 186 pp., published by the State, New Haven, 1837.

This report consists of three parts: 1. An economical report, in which the mineral resources of the state are described under the following heads: — metals; coal; plumbago; gems; polishing and grinding materials; soapstone and potstone; materials for alkaline and earthy salts; material for bricks, pottery, porcelain, and glass; fire stone; fluxes; quicklime and water cement; stove paints; decolorizing carbonaceous slate; material for architecture and decoration; material for flagging, tiling and paving; material for agriculture; mineral springs. 2. Scientific report, in which the minerals and ores occurring in Connecticut are described and classified. 3. A catalogue of the collections, containing 595 specimens.

259. **Shepard, Charles Upham.**

Biography.

Am. Jour. Sci., (3) xxxi, 482, 483, 1886.

260. Silliman, B.

Sketch of the mineralogy of the town of New Haven. Connecticut Acad. Arts Sci., Mem., i, 83-96, 1810.

Description of the various geological features of New Haven and its immediate vicinity — sand plain (made from material worn from the surrounding hills); various elevations surrounding the town, both trap, sandstone, and crystallines ("micaceous schistus, magnesian schistus"). (The above article was written in 1806.—*Ed.*)

261. Silliman, B., and Kingsley, J. L.

An account of the meteor, which burst over Weston, in Connecticut, in December, 1807, and of the falling of stones on that occasion, with a chemical analysis of the stones.

Connecticut Acad. Arts. Sci., Mem., i, pp. i, 141-161, 1810.

Published earlier in the Connecticut Herald and in Trans. Am. Phil. Soc. of Philadelphia, 1808.

Accounts by Nathan Wheeler, Elihu Staples, and others who witnessed the fall. Original meteor 300 feet in diameter fell in fragments at six localities, the most remote being ten miles apart. Description is given of the stone at large; the pyrites; the malleable iron; the black irregular masses; the crust; the globular bodies. The analysis showed silex 51.5; chloride of iron 38; magnesia 13; oxide of nickel 1.5; sulphur 1.

(This is the first description of an American meteorite in which the phenomena of the fall and the composition of the rock are given. Fragments of this meteor are in Yale University museum.— *Ed.*)

262. Silliman, B.

Mineralogical and geological observations on New Haven and its vicinity.

Am. Min. Jour., i, 139-149, 1814. Abstract: Jour. Phys. Chim., lxxv, 75-79, 1812; Am. Jour. Sci., (1) i, 55-56, 1818; Treatise on Mineralogy and Geology, Cleaveland, 555, 1822.

The following geological matters are discussed: Alluvial plain, sandstone, granite; "East and West mountains," Pine Rock, of greenstone; slate of West Haven; magnetic sand on the beach; serpentine; limestone.

263. Silliman, B.

Localities of mineral and animal remains and acknowledgment of specimens received.

Am. Jour. Sci., (1) i, 237-243, 1819.

Mention of rose quartz from Southbury; plumbago from Cornwall; coal from Suffield and Southington; sulphate of barytes, with coal, etc.; molybdena from Pettipaug, Saybrook; beryl from Haddam.

264. **Silliman, B.**

Mineralogical and geological observations on New Haven and its vicinity.

Am. Jour. Sci., (1) i, 55-56, 1819.

An account of native copper found in the drift at Wallingford.

265. **Silliman, B.**

Sketches of a tour in the counties of New Haven and Litchfield in Connecticut, with notices of the geology, mineralogy, and scenery.

Am. Jour. Sci., (1) ii, 201-235, 1820.

Conversational description, in diary form, of a tour through western Connecticut, touching at New Haven, Watertown, Goshen, Salisbury, Kent, New Preston, New Milford, Woodbury; mentions Secondary greenstone ranges, Primitive slate rocks, gneiss, granite, limestone, and iron ores; describes the scenery as well as various manufactories, etc.

266. **Silliman, B.**

Remarks made on a short tour between Hartford and Quebec in the autumn of 1819. 407 pp., 12°, New Haven, 1820; 2d ed., 443 pp., 9 pls., New Haven, 1824.

Describes tour from Hartford over Talcott mountain through Canton, New Hartford, and thence up the Farmington river to Massachusetts. The central area of Secondary sandstone and trap or greenstone is described. "The ridges of greenstone repose almost universally upon sandstone." The topography of the trap ridges and the talus slopes is explained. "It is amusing to observe how immediately the materials of the fences and the buildings, so far as they are constructed of stóne, change as soon as the geology of the country changes."

The western crystallines are described as gneiss in "high, rounded, Primitive hills."

267. **Silliman, B.**

Remarks on red sandstone of the Connecticut region.

Am. Jour. Sci., (1) iii, 221, 222, 1821.

Mentions general relation of "trap-formation" of New England. Ridges of columnar greenstone trap reposing on red sandstone rock, beneath which lie slaty bituminous rocks; in the latter were found, at Westfield, fish impressions and copper minerals.

268. **Silliman, B.**

Notice of "Geological essays, or an inquiry into some of the geological phenomena, to be found in various parts of America and elsewhere — By Horace H. Hayden, Esq., member of the American Geological Society."

Am. Jour. Sci., (1) iii, 47-57, 1821.

Discussion of Mr. Hayden's theory that the alluvial region skirting the Atlantic Ocean is the result of the operation of currents (whose cause is the deluge of Noah) that flowed from northeast to south-

west, or from north to south, over the whole continent of America. Discusses importance of rock decay and soil formation.

(Well worth reading as indicating the unsettled state of geology at this period.— *Ed.*)

269. **Silliman, B.**

Ice caves at Meriden and Northford.

Am. Jour. Sci., (1) iv, 174-177, 1822.

Account of the ice deposits that are found in the deep ravines and gorges at Meriden and Northford.

270. **Silliman, B.**

Ice caves at Salisbury.

Am. Jour. Sci., (1) viii, 254, 1824.

Account of the ice deposits that are found in the deep ravines and gorges of Salisbury.

271. **Silliman, B.**

Bakewell's Introduction to Geology. Edited by Benj. Silliman; with appendix. Outline of Silliman's course of lectures at Yale. 1st Am. ed., 1829.

Mentions Connecticut river terraces, gorge at Middletown, influence of geological structure on people, intrusive trap, bowlders, East Haven conglomerate, diluvium.

272. **Silliman, B.**

Igneous origin of some trap rock.

Am. Jour. Sci., (1) xvii, 119-131, 1830.

Discusses question of igneous or aqueous origin of trap, particularly at Rocky Hill, 3 miles S. S. W. of Hartford; "this trap is a crystalline, and the sandstone under it a mechanical rock;" "trap deposited and aggregated," "from a state of chemical mobility"; vesicular character of trap described; contact described in detail. "For myself I must say that the effects that have been produced both upon the trap and the sandstone . . . are such as I can attribute to no agent but fire." . . . "The effects on both rocks are just such as . . . we must expect from intense heat acting under great pressure."

(If this early work of Silliman had been kept in mind, and his method of investigation followed, there probably would never have been two contradictory opinions regarding the origin of the trap rock of Connecticut.— *Ed.*)

273. **Silliman, B.**

Notice of a report on the geological survey of Connecticut, by Prof. C. U. Shepard.

Am. Jour. Sci., (1) xxxiii, 151-175, 1837.

Largely an extended abstract of Shepard's report, 258.

274. **Silliman, Benjamin.** (1779-1864.)

Biography.

Fisher: Life of Benjamin Silliman, 2 vols., New York, Scribner and Co., 1866.

Dana: Am. Jour. Sci., (2) xxxix, 1-10, 1865.
Caswell: Nat. Acad. Sci., Mem., i, 101-112, 1877.
Pop. Sci. Mon., xxiii, 259-266, 1883.

275. **Silliman, B., Jr.**

Dr. Percival, the original discoverer of the crescent-formed dikes of trap in the New Red sandstone of Connecticut.

Am. Jour. Sci., (1) xlvi, 205-206, 1844.

Credit given to Percival to correct a misunderstanding.

276. **Silliman, B., Jr.**

Report on the intrusive traps of the New Red sandstone of Connecticut.

Am. Jour. Sci., (1) xlvii, 107, 108, 1844: Assoc. Am. Geol., Proc., 14, 15, 1844; Neues Jahrb., 728, 729, 1845.

Abstract of the conclusions concerning the origin and formation of the sandstone and trap of Connecticut. Sandstones laid down in "angular position," dipping easterly; igneous dikes entered sediments far below surface; present topography due to enormous northerly current.

277. **Silliman, B., Jr.**

On fossil trees found at Bristol, Connecticut, in the New Red sandstone.

Am. Jour. Sc., (2) iv, 116-118, 1847.

Description of two fossil coniferous trees found in a sandstone quarry on the banks of the Pequabuck river near Bristol.

278. **Silliman, B., Jr., and Whitney, J. D.**

Notice of the geological position and character of the copper mine at Bristol, Connecticut.

Am. Jour. Sci., (2) xx, 361-368, 1855.

(See Whitney and Silliman, 296.)

279. **Smith, A.**

On the water courses and the alluvial and rock formations of the Connecticut river valley.

Am. Jour. Sci., (1) xxii, 205-231, map, 1832.

Statement of the course and extent of the valley of the Connecticut. General discussion of the disintegration of primitive rock strata into gravel, sand, clay. Mention of the Primitive (crystalline) formation. Description of the Secondary (sandstone and trap) formation and discussion of its origin.

280. **Smock, J. C.**

Geological-geographical distribution of the iron ores of the eastern United States.

Am. Inst. Min. Eng., xii, 130-144, 1884.

The Connecticut ores discussed are magnetite, Laurentian, Fairfield

county; titaniferous magnetite, Huronian, "in gneiss in Connecticut"; limonite, Lower Silurian, Litchfield county; iron coloring the Triassic sandstones and shales.

281. **Stodder, C.**

On the occurrence of clay on the banks of the Farmington river, Connecticut.

Boston Soc. Nat. Hist., Proc., vi, 138-139, 1857.

Description of clay concretions or segregations in clay on the Farmington river, Windsor.

282. **United States Geological Survey.**

The following titles of papers issued by the United States Geological Survey are listed under the names of the authors: —

Davis, 83, 98; Emerson, 112, 113; Fuller, 119; Gannett, 120, 121; Gregory, 123, 124; Hobbs, 155, 156, 159; Knowlton, 180; Marsh, 206; Newberry, 221; [Newell], 223, 224; Pynchon, 239; Rafter, 240; Ries, 244, 245; Russell, 252, 253; Walcott, 288.

MINERAL RESOURCES OF THE UNITED STATES (OLD SERIES).

1882, nickel, cobalt, 401 (history of the mine in Chatham). "Ores, minerals, and mineral substances of industrial importance which are at present mined" are feldspar, flagging stone, granite, limonite, marble, sandstone, trap. Localities given, 672. Ores, etc., "which are not at present mined" are apatite, arsenopyrite, agate, barite, beryl, bismuth, bornite, calamine, cassiterite, chalcocite, chalcopyrite, corundum, clay, galenite, garnet, graphite, hydraulic limestone, limonite, magnetite, malachite, molybdenite, niccolite, pyrite, pyrrhotite, quartz, rutile, siderite, smaltite, sphalerite, talc, topaz, uraninite. Localities given, 672-674.

1883-1884, cobalt, 544; feldspar, 933; mica, 908; mineral waters, 908; tungsten, 574.

1885, building stone, 397; fertilizers, 469; iron, 182; lime, 410; mineral waters, 537; precious stones, 439.

1886, granite, 537; iron, 14, 17, 42; mineral waters, 716; structural materials, 522.

1887, granite, 573; iron, 11; lime, 532; minerals, 714.

1888, list, with localities, of minerals and rocks mined and not mined, 714-716; brick, 558, 566; granite, 536; iron, 14; lime, 555; mineral waters, 626, 630.

1889-1890, brown hematite, 40; granite, 374, 385; iron, 10, 17, 24, 35, 36; limestone, 373, 385, 386 (analysis); mineral waters, 522; sandstone, 374, 385.

1891, clay, 502; granite, 457, 458; iron, 12, 27, 61; limestone, 464, 465; mineral waters, 603, 604; sandstone, 401.

1892, beryl, 766; granite, 706, 707; iron, 26, 34; limestone, 711; mineral waters, 824, 826; sandstone, 710; topaz, 764.

1893, granite, 545; infusorial earth, 678; iron, 26, 28, 35; limestone, 555; mica, 753; mineral waters, 774, 776, 787; sandstone, 553; stone at World's Columbian Exposition, 562.

1894-1895, granite, 459; limestone, 496; sandstone, 486; iron, 192.

ANNUAL REPORTS.

1894-95, pt. iii, iron ore, 192, 201; pt. iv, granite, 459; limestone, 496; mineral waters, 712; sandstone, 486.

1895-96, pt. iii, granite, 764; limestone, 792, 802; mineral waters, 1032; sandstone, 779.

1896-97, pt. v, brownstone (analyses), 1030; feldspar, 1365; granite, 957; limestone, 1049; mineral waters, 1377; sandstone, 1017-1021.

1897-98, pt. vi, clay, 354; feldspar, 657; granite, 208, 213, 232; limestone, 280, 283, 287; mineral springs, 661, 667; Portland cement, 487, 492; quartz, 657; sandstone, 264-267.

1898-99, pt. vi, clay, 515; feldspar, 693; granite (analyses and tests), 277, 362, 364; limestone (analyses), 346, 370; mineral waters, 756; quartz, 588; sandstone (analyses and tests), 339, 365-369; tourmaline, 577; trap (analyses and tests), 364, 365; tungsten, 594.

1899-1900, pt. vi, beryl, 450; clay, 362, 363; garnet, 467; granite, 336-340; limestone, 357-360; mineral waters, 598, 607; sandstone, 353, 365; silicified wood, 455; stone, 335.

MINERAL RESOURCES OF THE UNITED STATES (NEW SERIES).

1900, clay, 695, 698, 728; feldspar, 895; flint, 895; granite, 662, 664, 667; infusorial earth, 794; iron ores, 43, 57; limestone, 662, 685; lithiophilite, 242; mineral waters, 901; pig iron, 96; pottery, 715; sandstone, 662, 670, 673; scheelite, 258; spodumene, 241; tourmaline, 761; trap, 666.

1901, barytes, 915; clay, 674-677, 711; feldspar, 938; flint, 936; granite, 650; ilmenite, 272; infusorial earth, 798; iron, 60, 76, 100, 103; limestone, 667; mica, 875; mineral waters, 962; monazite, 950; pig iron, 86; pottery, 700; quartz, 800; rutile, 272; sandstone, 656; stone, 643; trap, 654; tripoli, 798; tungsten, 263.

1902, barytes, 945; brick, 719; clay, 707, 747, 757; corundum, 831, 886; essonite, 837; feldspar, 973; flint, 972; granite, 678; iron, 43, 59, 67, 68; limestone, 698; marble, 693; mica, 985; mineral waters, 996; pig iron, 86, 87; pottery, 734, 738; quartz, 883; sandstone, 684; stone, 669; tourmaline, 841; tile, 719; trap, 669; tungsten, 286.

1903, ammonia, 629; asbestos, 1112, 1114; brick, 796, 809; clay, 796, 860; coal tar, 624; feldspar, 1119; flint, 1117; granite, 758, 766, 768; garnet, 1005; gas, 611, 619, 622; iron, 43, 59, 67, 68; limestone, 758, 786; marble, 758, 781; mineral waters, 1139; pig iron, 93-95; pottery, 796, 809; quartz, 1004; sandstone, 758, 770; spodumene, 313; steel, 103, 104, 106; tourmaline, 926; tile, 796, 809; trap, 769; tungsten, 307.

1904, ammonia, 669; asbestos, 1137; bismuth, 375; brick, 863, 871; clay, 850, 859; coal tar, 664; columbite, 1225; feldspar, 1144; flint, 1143; gas, 654, 662; granite, 805; iron, 40, 53, 62; limestone, 805; marble, 805; mica, 1175, 1181; mineral waters, 1187, 1190; molybdenum, 339; pig iron, 79; pottery, 882, 892; quartz, 998, 1009; sand, 1149; sandstone, 80, 805; steel, 88, 91, 101; tourmaline, 942, 954; tile, 863, 871; trap, 805; tungsten, 333.

WATER SUPPLY AND IRRIGATION PAPERS.

The following papers, published by the U. S. Geological Survey as Water-Supply and Irrigation Papers, contain statistical matter more or less closely related to geology: —

No. 35, 1900. Daily readings of height of Connecticut river at

Hartford, given for period February 8, 1896, to December 31, 1899, inclusive, 42-44.

No. 44, 1901. Profiles of rivers in the United States, 12-14. Discusses and illustrates profiles of Connecticut and Housatonic rivers from source to mouth.

No. 47, 1901. Daily readings in height of the Connecticut river at Hartford given for the year 1900, and for Housatonic at Gaylordsville from October 23 to December 31, 1900, 35.

No. 65, 1902. Daily readings of height of the Housatonic at Gaylordsville from October 23, 1900, to December 31, 1901; also list of undeveloped water powers along that stream, 87-90.

No. 75, 1903. Table and diagram of monthly discharge of Housatonic at Gaylordsville, 24.

No. 76, 1903. Housatonic river; quality of water, 84, 85; daily gage height, 1900-02 inclusive, 93-95; current meter discharge measurements, 104.

No. 82, 1903. Daily readings of Connecticut river at Hartford for the year 1902, 48, 49.

No. 97, 1904. A study of the Connecticut River drainage basin, including daily gage height at Hartford for 1903, 80-83; the Mianus river near Stamford for 1903, 94-114; Byram river at Pemberwick, Greenwich, and Riverville for 1903, 118-124.

No. 124, 1905. Daily gage reading of Connecticut river at Hartford, for 1904, 121-122; daily gage reading of the Housatonic at Gaylordsville, 147-152; of Shetucket near Willimantic for 1904, 112-113.

No. 144, 1905. Distribution of chlorine in ground water, and tables showing determinations for the state, 22-28, map.

No. 149, 1905. List of deep well borings in Connecticut, 23-24.

283. Upham, W.

The succession of Glacial deposits in New England.
Am. Assoc. Adv. Sci., Proc., xxviii, 299-310, 1880.

Description of the occurrence and extent of the various drift deposits,— till, stratified deposits, moraines, etc., of New England. Discussion of origin. No description of any particular glacial phenomena of Connecticut.

284. U[pham],W.

[Abstract of] "Some typical eskers of southern New England," by J. B. Woodworth.
Am. Geol., xiv, 396, 1894.

Woodworth's article states that eskers were deposited in channels of drainage upon, in, or beneath the waning ice-sheet. (See Woodworth, 301.)

285. Valcherville, M. de.

Highland Park, Manchester.
Connecticut Quart., i, 299, 1895.

Describes the old Wyllys copper mine.

286. Walcott, C. D.

The Taconic system of Emmons, and the use of the name Taconic in geologic nomenclature.

Am. Jour. Sci., (3) xxxv, 229-242, 307-327, 394-401, map and section, 1888. Abstract: Nature, xxxvii, 500, 1888. Review by J. Marcou: Am. Geol., ii, 10-23, 67-88, 1888.

This exhaustive discussion of the Taconic question is subdivided as follows: 1. The Taconic area and geologic work within it; 2. Geology of the Taconic area as known at the present time; 3. Geology of the Taconic area as known to Dr. Emmons; 4. Comparison and discussion; 5. Nomenclature. (See Emmons, 115.)

287. Walcott, C. D.

Synopsis of conclusions on the "Taconic of Emmons." Internat. Cong. Geol., Rept. Am. Comm., 25-29, 1888; Am. Geol., ii, 215-219, 1888.

Name Taconic "based on error and misconception originally, and used in an erroneous manner since"; and should not be used as indicating stratigraphic position.

(See also, Walcott, 286.)

288. Walcott, C. D.

Correlation papers, Cambrian.

U. S. Geol. Surv., Bull. No. 81, 1-447, 3 pls., 1891.

Historical review of the geologic and paleontologic work, and summary of the present knowledge of the Cambrian areas of North America. Mention of the quartzite of Canaan.

289. Warren, J. C.

Geological position of the Mastodon.

Boston Soc. Nat. Hist., Proc., iii, 111, 1849.

Brief mention of the remains of mastodons found in Connecticut, "about midway between the Connecticut River and the Hudson."

290. Webster, J. W.

Localities of minerals, observed principally in Haddam in Connecticut, in September, 1819.

Am. Jour. Sci., (1) ii, 239, 240, 1820.

Mention of tourmaline and epidote in mica slate and gneiss; chrysoberyl in a granite vein traversing the gneiss, containing also garnet and tourmaline; actinolite in mica slate; all of the above near Haddam. Globular concretion of gneiss near Jewett City; tourmaline at Bozrah; transparent garnets at Tolland, also graphite.

291. Wells, D. A.

On the Connecticut valley sandstone formations.

Boston Soc. Nat. Hist., Proc., iii, 339-340, 1850.

The upper members of the Connecticut River sandstones are of an entirely different age from the lower. This is evidenced by the limitation of the fossils to the upper beds, and by the different lithological characters.

292. Wells, D. A.

On the origin of stratification.

Boston Soc. Nat. Hist., Proc., iv, 108-110, 1851; Am.

Assoc. Adv. Sci., Proc., vi, 297-299, 1852.

The shales and sandstones of the Connecticut Triassic are cited to prove that all strata are not produced either by an interruption of deposition or by a change in the quality of the material deposited.

293. **Wells, D. A.**

Evidences of glacial action in southeastern Connecticut.

Pop. Sci. Mon., xxxvii, 196-201, 1890.

Description of several large glacial bowlders in the region between Groton and Noank, at Fisher's island, and near Norwich.

294. **Wells, D. A.**

Remarkable bowlders.

Pop. Sci. Mon., xl, 340-346, 1892.

Description of several large bowlders occurring at Montville, about midway between Guilford and Leete Island, and in Massachusetts.

295. **Westgate, L. G.**

A granite-gneiss in central Connecticut.

Jour. Geol., vii, 638-654, 4 figs., map, 1899.

The gneiss at Maromas is shown to be igneous; its field relations and petrography are described in detail.

296. **Whelpley, J. D.**

Trap and sandstone of the Connecticut valley.

Assoc. Am. Geol., Proc., vi, 61-64, 1845.

Originally the sandstone area covered the Housatonic and Connecticut valleys and the space between. Woodbury and larger portions in Connecticut valley preserved because they had hard trap dikes in them. These dikes "acted as so many dams and headwaters against the denuding flood," thus protecting the sandstone. The crescentic form of dikes is due to irregularities of vent.

297. **Whitney, J. D., and Silliman, B., Jr.**

Notice of the geological position and character of the copper mine at Bristol, Connecticut.

Am. Jour. Sci., (2) xx, 361-368, 1855.

The mine is situated at the contact of the sandstone and the metamorphic rocks. The copper ore ("vitreous and variegated" types with some copper pyrites) is obtained from the micaceous and hornblende slates, talcose micaceous slate, and sandstone. A history of the mine is given; opened in 1836; not worked extensively until 1846. The sandstone is of Liassic age, and the metamorphic rocks belong to the Paleozoic system.

298. **Whittle, C. L., and Davis, W. M.**

The intrusive and extrusive Triassic trap sheets of the Connecticut valley.

Mus. Comp Zoöl., Bull., xvi, 99-138, 1 pl., 1889.

(See Davis and Whittle, 100.)

299. **Williams, S.**

Observations and conjectures on the earthquakes of New England.

Am. Acad. Arts Sci., Mem., i, 260-311, 1785.

The paper is divided into two parts: 1. An historical account of earthquakes of 1638, 1658, 1663, 1725, 1755, and of several minor shocks; 2. Causes of earthquakes.

300. **Winchell, N. H.**

Comparative strength of Minnesota and New England granites.

Am. Assoc. Adv. Sci., Proc., xxxii, 249, 250, 1884.

Abstract of article showing by a series of comparative tests that the Minnesota granites are stronger than those of New England. The Connecticut granites tested came from Mystic river, Stony Creek, Millstone point, Greenwich, New London.

301. **Woodworth, J. B.**

Some typical eskers of southern New England.

Boston Soc. Nat. Hist., Proc., xxvi, 197-220, 1894.

The typical eskers of southern New England are most easily explained by assuming a subglacial origin, but certain ones demand a channel open to the sky; esker at Compounce Pond described; others in Connecticut mentioned.

302. **Author unknown.**

[Review of] "Outline of the geology of England and Wales, with an introductory compendium of the general principles of the science and comparative views of the structures of foreign countries. By Rev. W. B. Conybeare and William Phillips. Pt. I, 470 pp., London, 1822."

Am. Jour. Sci., (1) vii, 203-240, 1824.

Comparison of the red sandstone of Connecticut with the marl and Old Red sandstone of England.

303. **Author unknown.**

What constitutes the Taconic range of mountains?

Am. Geol., vi, 247, 1 pl., 1890.

Quotations from Dr. Asa Fitch, Prof. J. D. Dana, and Mr. C. D. Walcott, in order to verify the claims of Dr. Emmons as to what constitutes the Taconic range of mountains.

LIST OF MAPS.

500. **Blake, W. P., and Hitchcock, C. H.**

Geological map of the United States.

Atlas of the U. S. and the world by Gray, folio, Philadelphia, 1871; Statistics of mines and mining in the states and territories west of the Rocky mountains, 5th report by R. W. Raymond, Washington, 1873; Statistical atlas of the United States based on results of the 9th Census, 1870, pls. xiii, xiv, Washington, 1875; Special report for the Centennial, 1876; Smithson. Contr. Knowl., 1876; Die Vereinigten Staaten von Nord-Amerika (F. Ratzel), i, München, 1878.

Connecticut is marked "Eozoic" except the Connecticut valley and Pomperaug areas of "Jurassic and Triassic" rocks. Note states: "There may be some metamorphic Palæozoic formations included in the Atlantic portions of the Azoic."

501. **Bradley, F. H.**

Geological chart of the United States east of the Rocky mountains and of Canada. Folder, 16 by 24 inches, New York, 1875.

The formations shown in Connecticut are: Archæan, all that part of the state east of the Triassic; Lower Silurian, nearly all of western Connecticut; Upper Silurian, in eastern Litchfield and western Hartford county; Triassic, central Connecticut and Southbury. Scale approximately 1 inch=90 miles.

502. **Chapin, J. H.**

Map showing the triangulation of Connecticut, by the United States Surveys.

Meriden Sci. Assoc., Trans., iv, 51, 1890.

Scale, ⅔ inch=10 miles.

503. **Crosby, W. O.**

Map of the proposed sites of the dams in the valley of the Housatonic and of the Tenmile river.

Tech. Quart., xiii, No. 2, 123, 1900.

A topographic map, showing the relations of the Tenmile and Housatonic valleys, extending from Dover Plains to Pawling, including part of the Housatonic river in Connecticut. Scale 1 inch=2 miles.

504. **Dana, J. D.**

Topographic map of the New Haven region.

Connecticut Acad. Arts Sci., Trans., ii, 45, 1873.

Extends north from the Sound to include Mount Carmel. Includes Woodbridge hills on the west, and lake Saltonstall on the east.

The various elevations are indicated by hachures. Rivers, railroads, and a few roads are indicated. Scale $\frac{1}{16}$ inch = 1 mile.

505. **Dana, J. D.**

Map of the New Haven region.

Am. Jour. Sci., (3) x, 171, 415, 1875.

Embraces a tract about four miles on each side of the harbor, extending north, including Mount Carmel. Shows geography and some topography. Scale $\frac{1}{16}$ inch = 1 mile.

506. **Dana, J. D.**

Map of the Connecticut valley and part of the coast of southern New England.

Am. Jour. Sci., (3) x, 499, 1875; xxv, pl. v, 1883.

Gives main geological features and some topography of an area along the Connecticut river from Northampton south; 5 to 12 miles on the east side, 20 to 35 miles on the west side. Scale approximately 1 inch = 12 miles.

507. **Dana, J. D.**

Map of Dutchess and the adjoining counties of eastern New York, with a portion of western Connecticut and southwestern Massachusetts.

Am. Jour. Sci., (3) xvii, 379, 1879.

Locates the limestone belts of western Connecticut, about 12 miles wide, down to about 3 miles south of New Fairfield. Scale $\frac{1}{16}$ inch = 1 mile.

508. **Dana, J. D.**

Map of limestone areas of Westchester county, New York.

Am. Jour. Sci., (3) xx, pl. v, 1880.

Takes in that part of Connecticut west of the line running south from Danbury, and south of a line running west from that town. Locates the limestone areas in color. Scale 1 inch = 3 miles.

509. **Dana, J. D.**

Map of limestone areas of Dutchess, Westchester, and Putnam counties, New York, and part of western Connecticut, with the Archæan of Putnam county and the Palisade trap range.

Am. Jour. Sci., (3) xx, pl. viii, 1880.

Includes that part of Connecticut west of a line running north and south at a distance of about 10 miles east of Salisbury. Locates the limestone areas. Scale 1 inch = 10 miles.

510. **Dana, J. D.**

Section of the Connecticut river during the flood from the melting glacier.

Am. Jour. Sci., (3) xxiii, pl. ii, 1882.

Includes the central portion of Connecticut, extending at the south from a little west of New Haven to a little east of the mouth of the Connecticut. Approximately the same width at the northern part of the

state. Transverse section of river bed also given. Scale 1 inch=20 miles.

511. **Dana, J. D.**

Geological sketch map of the Taconic range.

Geol. Soc. London, Quart. Jour., xxxviii, pl. xvii, 1882.

Map of Taconic area from Burlington, Vermont, to New York City. Connecticut formations are mapped as Archæan, crystalline limestone and Taconic schists. Scale approximately 1 inch=5 miles.

512. **Dana, J. D.**

Map of the New Haven region.

Am. Jour. Sci., (3) xxvi, 342, 1883.

Includes area south of Mount Carmel, and between Saltonstall on the east and Woodbridge heights on the west. Principal topographic features marked; also streets and roads. Outline of the flood-made terrace is indicated. Scale $\frac{1}{10}$ inch=1 mile.

513. **Dana, J. D.**

Map of the New Haven plain, showing its original features.

Am. Jour. Sci., (3) xxvii, pl. ii, 1884.

Includes the plain on which the city is built and the adjoining hills. Extends as far north as Centerville, and south to just below mouth of West river. Gives outline of terrace area, river channels, and kettle-holes. Elevations indicated by figures. Scale 2 inches=1 mile.

514. **Dana, J. D.**

Map of the southern end of a great synclinal in the Taconic range.

Am. Jour. Sci., (3) xxviii, pl. iii, 1884.

Locates limestone, mica schist, and some ore pits of the area immediately around, and to the west and north of Salisbury. Scale 8 inches=1 mile.

515. **Dana, J. D.**

Geological sketch map of the Taconic region, southern part.

Am. Jour. Sci., (3) xxix, pl. ii, 1885.

Locates schist, gneiss, quartzite, and limestone of northwestern Connecticut. Scale ½ inch=1 mile.

516. **Dana, J. D.**

Maps of the New Haven region.

Am. Jour. Sci., (3) xlii, 79-110, 1891.

Pl. I. Map of New Haven. Shows topography of the region by hachures. Scale 1 inch=2½ miles. Pl. II. Map of the New Haven region before 1640. Location, in color, of East Rock, Mill Rock, Pine Rock, and the southern part of West Rock. Location of kettle-holes and terraces and old creek beds. Elevations given. The part of the city mapped is the original half-mile square bounded by George, State, York, and Wall streets. The northern part of the harbor is included. Scale 1 inch=2 miles. Pl. III. Map of East Rock. A detailed geological map of East Rock, including Snake Rock and Whitney peak. Scale 1 inch=800 feet. Pl. VI. West Rock. Scale 1

inch=400 feet; contour interval 20 feet. Fig. 1. Map of Pine Rock. Scale 1 inch=1,000 feet. Fig. 5. Map of Mill Rock. Scale 1 inch=1,000 feet. Fig. 16. Wintergreen notch. Page 44. Trap areas of central Connecticut. Scale 1 inch=8 miles. Page 82. Map of Round hill and vicinity. Scale 1 inch=½mile. Page 112. Stony Creek and the Thimbles. Scale 1 inch=½ mile.

See also, The Four Rocks of the New Haven Region. New Haven, 1891.

517. **Dana, J. D.**

Map of the Triassic of Connecticut, from Hartford down to the Sound. Reproduction of part of Percival's map.

Am. Jour. Sci., (3) xlii, pl. xvi, 1891.

Scale approximately 1 inch=6 miles.

518. **Davis, W. M.**

Sketch maps of Hanging Hills and trap sheet at Beckley station.

Mus. Comp. Zoöl., Bull., vii, pl. x, 1884.

519. **Davis, W. M.**

Modification of a portion of Percival's geological map of Connecticut (1842).

U. S. Geol. Surv., 7th Ann. Rept., 1887.

Locates, in color, the Triassic area of central Connecticut; principal trap ridges are indicated. Scale 1:503000.

520. **Davis, W. M.**

Sketch maps of trap ridges.

U. S. Geol. Surv., 7th Ann. Rept., 1877.

Trap ridges near South Britain, fig. 97; trap near Woodbury, fig. 99; Pond, Totoket, and Paug mountains, fig. 102.

521. **Davis, W. M.**

Sketch map of Massachusetts, Connecticut, and Rhode Island, giving location of Triassic area, and of ridges near Meriden.

Am. Jour. Sci., (3) xxxvii, 424, 1889.

522. **Davis, W. M.**

Outline map of southern New England.

Mus. Comp. Zoöl., Bull., xvi, pl. i, fig. 1, 1889.

Shows the Triassic area of the lower Connecticut valley (dotted) and Meriden area (black square). Scale 1 inch=100 miles.

523. **Davis, W. M.**

Sketch maps of faulted areas in Triassic.

Mus. Comp. Zoöl., Bull., xvi, 1889.

Lamentation mountain, fig. 2; Shuttle Meadow reservoir, fig. 3; faulted Triassic monocline, Meriden, fig. 9; Lamentation mountain, Chauncy peak, and Higby mountain, fig. 10a; Hanging Hills, fig. 11; area from Cook's gap to Short mountain, fig. 13; trap ridges and faults in the Meriden-New Britain district, fig. 16.

524. **Davis, W. M.**

Diagrammatic map of the Cretaceous peneplain in New England.

Geol. Soc. America, Bull., ii, 551, 1891.

Shows general location of Triassic lowlands and crystalline areas of the whole of Connecticut; also of middle and western Massachusetts, and western New York. Scale about 1 inch=90 miles.

525. **Davis, W. M.**

Sketch map of the Triassic area of Connecticut.

Am. Jour. Sci., (4) i, 2, 1896.

Locates main trap ridges and fault lines.

526. **Davis, W. M.**

Sketch maps and diagrams illustrating structure in the Triassic area.

U. S. Geol. Surv., 18th Ann. Rept., pt. ii, 1-192, 1898.

Uplands and lowlands, fig. 1; trap ridges, fig. 5; abnormal fault causing Vineyard gap, fig. 24; marginal faults and Lamentation fault block, fig. 25; South Glastonbury and South Manchester corners, fig. 32; trap ridges near southwest end of Lamentation block, fig. 33; consequent Jurassic drainage, fig. 36; antecedent Triassic drainage, fig. 37; drainage on the Cretaceous peneplain, fig. 40; pre-Glacial drainage fig. 50; existing drainage of the Connecticut Triassic area, fig. 51; Quinnipiac and Mill river headwaters, fig. 52.

527. **Davis, W. M.**

Geological map of the Triassic area of Connecticut.

U. S. Geol. Surv., 18th Ann. Rept., pt. ii, pl. xix, 1898.

Locates, in color, the following formations: Upper sandstones, posterior trap sheet, posterior sandstones and shales, main trap sheet, anterior sandstones and shales, anterior trap sheet, tufaceous deposits, under sandstones, intrusive trap sheets, dikes, crystalline areas. Locates also lines of faulting. Scale 1 inch=2 miles; contour interval 100 ft.

528. **Davis, W. M., and Griswold, L. S.**

The Connecticut valley Triassic area, and a portion of crystallines on either side.

Geol. Soc. America, Bull., v, 520, 1894.

Principal trap ridges indicated. Faults along eastern boundary and within Triassic shown. Scale 1 inch=20 miles.

529. **Davis, W. M., and Loper, S. W.**

Sketch map of about ten square miles near Meriden.

Geol. Soc. America, Bull., ii, 423, 1891.

Show parts of Highby, Chauncy, Lamentation, and Quarry blocks. Localities of fossiliferous anterior and posterior shales indicated.

530. **Davis, W. M., and Whittle, C. L.**

Map of Triassic area in Connecticut from Long Island Sound to the north bend of the Farmington river.

Mus. Comp. Zoöl., Bull., xvi, 137, pl. i, 1889.

Based on Percival's map of Connecticut. Gives location of trap ridges and main geographic features. Scale 1.35 inches=10 miles.

531. **Davis, W. M., and Whittle, C. L.**

Sketch maps of Triassic trap ridges.

Mus. Comp. Zoöl., Bull., xvi, 137, pl. iii, 1889.

Adjacent ends of Saltonstall and Totoket mountains, fig. 2; north end of Totoket mountain, fig. 3; Higby mountain, fig. 4; Chauncy peak, south end of Lamentation mountain, and Quarry ridge, Meriden, fig. 5; Notch mountain and eastern ridges of the Hanging Hills, fig. 6; Farmington mountain and its anterior ridge, fig. 7; Farmington river gap at Tariffville, fig. 8; Rock falls of Aramamit river, fig. 9; north end of Lamentation mountain, fig. 10; posterior ridges of Saltonstall mountain, fig. 11.

532. **Dewey, C.**

A geological map of the county of Berkshire, Massachusetts, and of a small part of the adjoining states.

Am. Jour. Sci., (1) viii, 1, 1824.

The northwest corner of Connecticut is mapped. The following formations are represented in color: mica slate, primitive limestone, quartz rock.

533. **Dorsey, C. W., and Bonsteel, J. A.**

Soil map of the Connecticut valley.

U. S. Dept. Agric., Bur. Soils, Rept. Field Oper. for 1899, 1900.

Connecticut area mapped extends from Glastonbury to the Massachusetts line, with a width of 5 to 10 miles. Different types of soil are shown in color. Scale 1 inch = 1 mile; base used is topographic map of 1893.

534. **Eggleston, J. W.**

Map of Woodstock pond, Connecticut.

Am. Jour. Sci., (4) xiii, 404, 1902.

Locates kames, kettle-holes, eskers, and terraces. Scale 1 inch = 1,500 feet.

535. **Emerson, B. K.**

Holyoke folio.

U. S. Geol. Surv., Geol. Atlas of U. S., Folio No. 50, 1898.

Topographic, historical, superficial and economic geology sheets of a strip about 2½ miles wide along the northern edge of Connecticut, between the meridians 72° 30′ and 73°. Locates, in color, the following formations: Washington and Becket gneisses, Hoosac schist, Chester amphibolite, Sugarloaf arkose, Longmeadow sandstone, Holyoke diabase, Chicopee shale, and Glacial deposits. Scale 1 inch = 2 miles.

536. **Emerson, B. K.**

Map of an area in West Norfolk.

U. S. Geol. Surv., Bull. No. 159, pl. v, 1899.

Detailed geological map, with section, of the Norfolk railroad cut, also map showing geology of region adjoining. Scale 1 inch = 1 mile.

537. **Emerson, B. K.**

Map of eastern half of Housatonic quadrangle.

U. S. Geol. Surv., Bull. No. 159, pl. ix, 1899.

Geological map of that part of Connecticut found on the Sandisfield topographic sheet; includes northern halves of Colebrook and Norfolk, with parts of Hartland and North Canaan. Scale approximately ½ inch = 1 mile.

538. **Fippin, E. O.**

Soil map of the Connecticut valley.

U. S. Dept. Agric., Bur. Soils, Rept. Field Oper. for 1903, 1904.

Map of soil types in Massachusetts and Connecticut. The Connecticut area mapped is on the Springfield, Granville, Hartford, Granby, Middletown, and Meriden topographic sheets. Base map is the topographic atlas of Connecticut. Scale 1 inch = 1 mile.

539. **Gregory, H. E.**

Map showing water-supplies in areas of limestone, sandstone, and crystalline rock, of Connecticut.

U. S. Geol. Surv., Water-Supp. and Irr. Paper No. 114, fig. 17, 1905.

Scale 1 inch = 25 miles.

539a. **Gregory, H. E., and Robinson, H. H.**

Preliminary geological map of Connecticut.

Connecticut State Geol. and Nat. Hist. Surv., Bull. No. 7.

The base map, which was prepared especially for the present purpose, shows contours (100 feet), towns, streams, roads, etc. The geological formations, 42 in number, are shown in color. Quarries and clay pits are also located. The map is chiefly designed to differentiate rock types, and only seven formations are assigned to definite ages. Scale 1 inch = 4 miles.

(This is the first geological map of Connecticut issued since 1842. See Percival, 578. It is based on data supplied by several workers, and represents the present state of knowledge regarding the bed-rock geology of southern New England.— *Ed.*)

539b. **Gregory, H. E., and Rice, W. N.**

Maps and diagrams illustrating Connecticut geology.

Connecticut State Geol. and Nat. Hist. Surv., Bull. No. 6.

(See Rice and Gregory, 582a.)

540. **Griswold, L. S., and Davis, W. M.**

The Connecticut valley Triassic area.

(See Davis and Griswold, 528.)

541. **Hall, J., and Logan, W. E.**

Geological map of Canada and the United States.

(See Logan and Hall, 566.)

542. **Hitchcock, C. H.**

Geological map of United States and part of Canada.

Am. Inst. Min. Eng., Trans., xv, 486, 1886.

Laurentian, Silurian and Triassic areas of Connecticut, are indicated in color. Scale ⅛ inch = 100 miles.

543. **Hitchcock, C. H., and Blake, W. P.**

Geological map of the United States.

(See Blake and Hitchcock, 500.)

544. **Hitchcock, E.**

A geological map of the Connecticut valley.

Am. Jour. Sci., (1) vi, facing p. 1, 1823.

Hand-colored map of the region adjoining the Connecticut valley from Bellows Falls to New Haven. The area mapped in Connecticut is bounded on the west by a line from West Hartford to Milford; on the east by a line from Stafford to Saybrook. Formations shown are granite (at Branford), gneiss, hornblende slate, mica slate, chlorite slate, Primitive greenstone, argillite, Old Red sandstone, Secondary greenstone, Coal formation, alluvion. Section near New Haven shows dikes in Old Red sandstone. Scale 1 inch = 7 miles.

(The boundaries of formations as shown on this map are only approximately those drawn by later observers. Map is dated 1822. —*Ed.*)

545. **Hitchcock, E.**

Geological map of Massachusetts.

Am. Jour. Sci., (1) xxii, pl. 1, 1832.

Includes a strip about 5 miles wide along the north edge of Connecticut. Represents in color the following formations: mica slate, argillaceous and flinty slate, limestone, scapolite rocks, gneiss, hornblende slate, granite, New Red sandstone, greenstone, Tertiary, talcose slate. Scale approximately 4½ inches = 30 miles.

546. **Hitchcock, E.**

Map of the course of bowlders and striæ in North America.

Assoc. Am. Geol., pl. vii, 1843.

Includes northeastern United States, and a portion of Canada.

547. **Hitchcock, E.**

Geological map.

Smithson. Contr. Knowl., ix, pl. iii, 1857.

Surface geology, chiefly of the Connecticut valley. Includes a strip 10-15 miles on each side of the Connecticut river. Locates, in color, terraces, beaches, old river beds, ledges of rock, submarine ridges, old sea bottom, osars.

548. **Hobbs, W. H.**

Geological map of the northwest corner of Connecticut.

Jour. Geol., i, pl. ii, 1893.

Map includes an area of 26 square miles in the northwest corner of the state,— one-third of the town of Salisbury, a portion of eastern New York, and southwestern Massachusetts; shows areas of Everett schist, Egremont limestone, Riga schist, Canaan limestone. Scale 1 inch = 1 mile.

549. **Hobbs, W. H.**

Geological map of portions of Sheffield, Massachusetts, and Salisbury, Connecticut.

Jour. Geol., i, 785, 1893.

Map of a portion of the Housatonic valley east of Mount Washington. The geological structure is indicated. Shows areas of quartzite, Egremont limestone, Everett schist, Riga schist, Canaan dolomite, tremolitic limestone. Scale 1 inch=1 mile.

550. **Hobbs, W. H.**

Geological map of the Pomperaug valley, Connecticut.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. i, 1901.

Locates, in color, the following formations: Schist, gneiss, granite, conglomerate, sandstone, shale, basalt (anterior), shale and limestone (anterior), basalt (main), basalt (vesicular); also fault lines. Scale 1 inch=1 mile; contour interval 20 feet.

551. **Hobbs, W. H.**

Areas occupied by the Newark system.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. ii, 1901.

Trap and sediments of the Newark system in Connecticut located. Scale 1 inch=120 miles.

552. **Hobbs, W. H.**

Geological map of the vicinity of South Britain, Connecticut.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. viii, 1901.

Locates, in color, the following formations: Sandstone, conglomerate, gneiss (higher, lower), arkose (higher, lower), shale (anterior), basalt (higher, lower, lowest), shale (posterior); also fault lines and cold springs. Scale 4 inches=1 mile.

553. **Hobbs, W. H.**

Geological map of Orenaug hill, Woodbury, Connecticut.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. x, 1901.

Locates, in color, the following formations: Gneiss (higher, lower), arkose (higher, lower), basalt (higher, lower, lowest), shale (posterior), hornblende rock, sandstone, conglomerate; also cold springs and faults. Scale 1 inch=¼ mile.

554. **Hobbs, W. H.**

Topographic map of the Pomperaug valley, Connecticut.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. xiv, 1901.

Embraces an area 7½ miles east and west by 10 miles north and south (approximately). Scale 1 inch=1 mile; contour interval 20 feet.

555. **Hobbs, W. H.**

Map to illustrate the supposed stages in the erosion history of the Pomperaug basin, in the cycle which was ini-

tiated by the elevation and tilting of the Cretaceous plain of erosion.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, pl. xvii, 1901.

556. **Hobbs, W. H.**

Maps and diagrams, Pomperaug valley.

U. S. Geol. Surv., 21st Ann. Rept., pt. iii, 1901.

Newark areas of southern New England, p. 31; Pomperaug valley and vicinity, p. 33; trap ridges near South Britain, p. 35; trap ridges near Woodbury, p. 36; Oliver Mitchell brook, p. 41; development of the anterior basalt, p. 43; development of the main basalt, p. 45; Red spring, p. 52; Spring house section, p. 86; western basin wall, p. 87; contact along fault, p. 88; Mitchell's spring, western boundary of East hill, p. 91; William Curtis place, p. 92; fault bounding Horse and Pine hills, p. 102; Castle Rock, p. 111; southern part of the Pomperaug basin, p. 118; strike and dip observations in crystalline rocks, p. 123; topography of ridges, Southbury, p. 150; deep inglenook, Square Rock, p. 151; oblique inglenook, South Britain, p. 152; fault system of the Pomperaug valley, pl. ix; relation of drainage to faults, pl. xv; structure of the basin of the Shepaug river, pl. xvi.

557. **Hobbs, W. H.**

River map of the area surrounding the Pomperaug valley.

Jour. Geol., ix, 477, 1901.

Rivers have been traced from the U. S. Geological Survey atlas sheets, which are on a scale of one inch to the mile. Observed faults (extended) are shown, as are also the inferred approximate positions of joint or fault planees. Scale ½ inch = 1 mile.

558. **Hobbs, W. H.**

River map of Connecticut.

Jour. Geol., ix, 468, 1901.

This map, reduced from the two-sheet topographic map of Connecticut, shows the prominent "trough lines" and their trend. Scale 1 inch = 12½ miles.

559. **Hobbs, W. H.**

Map of the (Farmington) Still river and vicinity.

Geol. Soc. America, Bull., xiii, fig. 1, 1901.

Area immediately around Torrington, Winsted, and Robertsville. Locates drift barriers, limestone, ponded areas. Scale ½ inch = 1 mile; contour interval, 20 feet.

560. **Hobbs, W. H.**

Map of the (Housatonic) Still river and vicinity.

Geol. Soc. America, Bull., xiii, figs. 2, 3, 1901.

Area immediately around Danbury, Bethel, and New Milford. Locates drift, limestone, schist. Sketch map showing development of Still river. Scale ½ inch = 1 mile; contour interval, 20 feet.

561. **Hobbs, W. H.**

Geological map of the tungsten mine near Long hill, Connecticut.

U. S. Geol. Surv., 22d Ann. Rept., pt. ii, pl. i, 1901.

Locates, in color, hornblende gneiss, crystalline limestone, pegmatites, mica schist, quartz-hornblende-scheelite-epidote rock; also strike, dip, joints. Scale 1¼ inches=500 feet; contour interval 10 feet.

562. **Hobbs, W. H.**

Geological map of the vicinity of the Trumbull mine, Connecticut.

U. S. Geol. Surv., 22d Ann. Rept., pt. ii, pl. ii, 1901.

Locates schist-gneiss complex, hornblende gneiss, crystalline limestone. Scale 1¼ inches=1 mile; contour interval 20 feet.

563. **Hobbs, W. H.**

Sketch map of the Pomperaug valley, showing the distribution of the terrace deposits and of basalt trains.

Am. Jour. Sci., (4) xiv, 401, 1902.

Scale 1 inch=2 miles.

564. **Hobbs, W. H.**

Drainage system of Connecticut.

Geol. Soc. America, Bull., xv, pl. 46, 1904.

Shows rivers of Connecticut, and network of "lineaments" which control their course. Scale 1 inch=10 miles.

565. **Hovey, E. O.**

Map of the trap ridges of the East Haven region.

Am. Jour. Sci., (3) xxxviii, pl. ix, 1889.

Locates Pond Rock (Saltonstall ridge), and the smaller ridges within two miles of it; also south end of Totoket mountain and boundary of Triassic. Scale ½ inch=5,000 feet.

566. **Logan, W. E., and Hall, J.**

Geological map of Canada and the United States, from Hudson Bay to Virginia, and from the Missouri river to Newfoundland. Montreal, 1866; also on smaller scale in atlas to "Geology of Canada," 1863.

Review: Am. Jour. Sci., (2) xlix, 294-298, 1866.

Connecticut is left blank except the Connecticut valley "Trias," the limestone areas marked "Lévis" (Lower Silurian), and the schist of Salisbury marked "Lauzon." A carefully made colored map. Scale approximately 1 inch=25 miles.

567. **Loper, S. W., and Davis, W. M.**

Sketch map of about 10 square miles near Meriden.

(See Davis and Loper, 529.)

568. **Loughlin, G. F.**

Map of Glacial deposits in central Connecticut.

Connecticut State Geol. Nat. Hist. Surv., Bull. No. 4, pl. i, 1905.

Map of area from Massachusetts line to New Haven, and from Middletown to Southington. Areas of till, sand, high gravels, alluvium, clay of economic value, are shown. Scale approximately 1 inch=2 miles.

569. **Lyman, B. S.**

A conjectural map of the Connecticut and Massachusetts New Red sandstone.

Am. Phil. Soc., Proc., xxxiii, 202, 1894.

Scale 1 inch=16 miles.

570. **McGee, W. J.**

Map of the United States, exhibiting the present status of knowledge relating to the areal distribution of geologic groups. (Preliminary compilation.)

U. S. Geol. Surv., 5th Ann. Rept., for 1883-84, pl. ii, 1885.

Locates the eastern and western highlands of Connecticut as Archæan except a small area of Silurian in the northwestern part of the state. Locates also the central Jurassic-Triassic formation.

571. **Maclure, W.**

Geological map of the United States east of the Mississippi, accompanying "Observations on the geology of the United States."

Am. Phil. Soc., Trans., vi, 1809.

Connecticut colored as Primitive rocks, or uncolored, except two areas of Secondary, one reaching from Long Island Sound to Hartford, the other an oval area west of the Naugatuck. Base map used is by Samuel G. Lewis. Scale approximately 1 inch=90 miles.

(This is the earliest geológical map of the eastern part of the United States.—*Ed.*)

572. **Maclure, W.**

Geological map of the United States, accompanying "Observations on the Geology of the United States."

Am. Phil. Soc., Trans., (new series) i, pl. i, 1818, Abraham Small, Philadelphia, 1817.

In this second edition of Maclure's map the same formations are indicated in Connecticut as were shown in the first edition; viz., Primitive and Old Red sandstone. (This map reproduced in 1822 by P. Cleaveland, in "An Elementary Treatise on Mineralogy and Geology," 2d ed., Boston: and by Charles Moxon in "The Geologist," for 1843, London.—*Ed.*) Scale 1 inch=120 miles.

573. **Marcou, J.**

Geological map of the United States and the British provinces of North America.

Boston, Gould and Lincoln, 1853; Petermann, Mittheil., i, pl. xv, 1855; Soc. Geol. France, (2d series) xii, 1853; Geology of North America, Zurich, 1858.

Triassic shown as New Red sandstone or Keuper containing an area of copper trap. The rest of the state shown as eruptive and metamorphic rocks. Scale approximately 1 inch=90 miles.

(The formations are poorly located and poorly bounded. There seems little excuse for such crude mapping of Connecticut geology 13 years after the publication of Percival's Report.—*Ed.*)

574. **Martin, D. S.**

Geological map of New York city and vicinity, accompanied by a pamphlet of explanatory text. New York, 1888.

A part of Connecticut west of a line from Greenwich to Banksville is marked "Atlantic or Manhattan gneiss, age disputed." A belt of limestone projects into this area from the north. Scale 1 inch=2 miles.

575. **Mather, W. W.**

A geological map of Windham and New London counties.

Sketch of geology of New London and Windham counties, by W. W. Mather, 1832.

Ten bed-rock formations are shown in color, as are also quarries and mines of stone, iron, peat, clay, plumbago, and mineral springs. Two sections accompany the map. Scale approximately 1 inch=5 miles.

576. **Merrill, G. P.**

Map of the marble regions of western New England.

Smithson. Rept., pl. vii, 1886.

Includes the western part of Connecticut. The following formations are indicated: Archæan or Primitive, Potsdam, limestone, slate or gneiss.

577. **Percival, J. G.**

Map of Connecticut — east and west sections of Kensington, in Berlin.

Am. Jour. Sci., (1) v, 42, 1822.

Gives locality of sulphate of barytes, coal, lead, zeolites, shale; greenstone and sandstone ridges, alluvial flat; stalactites, quartz crystals, granite block, vein of carbonate of lime; mills, bridges, roads, etc.

578. **Percival, J. G.**

A geological map of Connecticut.

Report on the geology of the state of Connecticut. Published by the Legislature, New Haven, 1842.

The base map shows rivers, lakes, divides between streams, and

town boundaries. The geological boundaries are shown by dotted lines. The Secondary formations are separated from the Primary, and the divisions of the Primary are indicated by numbers, by Roman and Greek letters, and by various other characters. The trap of the Secondary and of the Primary are indicated, even to the small dikes. Scale approximately 1 inch=5½ miles.

(Considering the base map used and the area covered, probably no more accurate piece of geological mapping has ever been accomplished by a single individual.—*Ed.*)

579. **Petros (C. A. Lee).**

Map of two lakes, Salisbury.

Am. Jour. Sci., (1) v, 34-37, 1822.

Map of two lakes (Northeast and Little ponds); showing islands, swamp lands, moving bowlders.

580. **Putnam, B. T.**

Map showing location of iron mines east of the Hudson river.

Census of U. S., 10th Rept., xv, fig. 8, p. 83, 1886.

The map covers a portion of Litchfield county; southwestern portion of Berkshire county, Massachusetts, and Dutchess and Columbia counties, New York. Shows one mine in Connecticut, that in Kent. Scale 1 inch=1 mile.

581. **Pynchon, W. H. C.**

Map of the northwestern corner of Connecticut.

Connecticut Quart., v, 279, 1899.

Includes towns of Salisbury, Canaan, North Canaan, Sharon, and Cornwall. Shows topographic features and location of iron mines and furnaces.

582. **Rice, William North.**

Maps of Triassic areas.

Connecticut Board of Agric., Rept. for 1903, 98, 107, 1904.

One map of western Connecticut and Massachusetts, showing Triassic; another of trap areas in the vicinity of Hartford, Middletown, and Meriden.

582a. **Rice, W. N., and Gregory, H. E.**

Maps and diagrams illustrating Connecticut geology.

Connecticut State Geol. and Nat. Hist. Surv., Bull. No. 6.

Figure 1. Geological map of central Connecticut. Highland and lowland distinguished. Scale 1 inch=10 miles. Plate xiv. Preliminary geological map of Connecticut. A simplified edition of 539a. Scale 1 inch=6 miles. Plate xv. Triassic areas of eastern North America. Scale approximately 1 inch=120 miles. Plate xxiv. Map showing trap sheets and faults in central part of Triassic area of Connecticut. A clearly drawn map in black and white, slightly altered from Davis, 527. Scale 1 inch=2 miles. Figure 15. Sketch map showing faults near East Berlin. Scale 1 inch=1200 feet. Figure 17. Relations of

trap sheet, fault and river at Tariffville. Figure 19. Map of glacial striæ in Connecticut. Scale approximately 1 inch=20 miles. Figures 20-22. Three maps of the Farmington river and tributaries, showing pre-Glacial drainage, Glacial modifications, and present stage of development. Scale approximately 1 inch=20 miles.

582b. Robinson, H. H., and Gregory, H. E.

Preliminary geological map of Connecticut.

Connecticut Geol. and Nat. Hist. Surv., Bull. No. 7.

(See Gregory and Robinson, 539a.)

583. Russell, I. C.

Maps of the Connecticut valley sandstone areas.

U. S. Geol. Surv., Bull. No. 85, pls. i, iii, 1892.

Map of areas occupied by Newark system. Scale 1 inch=120 miles. Map of Triassic of the Connecticut valley, giving sedimentary, trap rock, and pre-Newark areas. Scale ⅓ inch=5 miles.

584. Smith, Alfred.

The Connecticut river valley.

Am. Jour. Sci., (1) xxii, 205, 1832.

Includes a strip about forty miles wide through the central part of Connecticut, showing the extent of the Primitive and Secondary formations. Scale 2½ inches=40 miles.

585. United States Geological Survey.

Map of the United States, exhibiting the progress made in the geographic survey.

U. S. Geol. Surv., 5th Ann. Rept., pl. i, 1883-84.

Shows the triangulation areas of Connecticut; also the area surveyed by other organizations than the U. S. Geological Survey.

586. United States Geological Survey.

Topographical atlas of the state of Connecticut.

United States Geological Survey in coöperation with the state of Connecticut. 1893.

An atlas consisting of 33 sheets covering Connecticut and parts of adjoining states. 1893. Scale 1 inch=1 mile; contour interval, 20 feet.

(This is the only complete atlas of Connecticut in existence. For a history and description of this map, see Connecticut State Geol. Nat. Hist. Surv., Bull. No. 7. The map may be obtained from the State Librarian, either bound or in separate sheets.—*Ed.*)

587. United States Geological Survey.

Topographic map of Connecticut.

United States Geological Survey in coöperation with the state of Connecticut. 1893.

A two-sheet wall map. Scale 1 inch=2 miles; contour interval 100 feet.

(Map may be obtained from the State Librarian unmounted or mounted on muslin with rollers.—*Ed.*)

588. Walcott, C. D.

Geologic map of portions of eastern New York, western Vermont, western Massachusetts, and northwestern Connecticut.

Am. Jour. Sci., (3) xxxv, pl. iii, 1888.

Formations mapped are: pre-Cambrian, Cambrian (Georgia, Potsdam); Calciferous, Chazy, Trenton; Hudson; Quaternary. Scale 1 inch = 10 miles.

589. Westgate, L. G.

Map of a granite-gneiss area.

Jour. Geol., vii, 639, 1899.

Map of the Maromas granite-gneiss area on the Connecticut river, below Middletown. Shows inclusions, quarries, dip and strike. Scale 1 inch = 1 mile.

590. Whittle, C. L., and Davis, W. M.

Map of the Triassic area in Connecticut.

(See Davis and Whittle, 530.)

591. Whittle, C. L., and Davis, W. M.

Maps of Triassic trap ridges.

(See Davis and Whittle, 531.)

INDEX

The books or papers referred to are indicated by the name of the author and the serial number. Numbers from 500 upward refer to maps.

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ADVERTISEMENT.

List of Bulletins of the State Geological and Natural History Survey of Connecticut.

1. First Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1903-1904.
2. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut; by Herbert William Conn.
3. A Preliminary Report on the Hymeniales of Connecticut; by Edward Albert White.
4. The Clays and Clay Industries of Connecticut; by Gerald Francis Loughlin.
5. The Ustilagineæ, or Smuts, of Connecticut; by George Perkins Clinton.
6. Manual of the Geology of Connecticut; by William North Rice and Herbert Ernest Gregory.
7. Preliminary Geological Map of Connecticut; by Herbert Ernest Gregory and Henry Hollister Robinson.
8. Bibliography of Connecticut Geology; by Herbert Ernest Gregory.
9. Second Biennial Report of the Commissioners of the State Geological and Natural History Survey, 1905-1906.

Bulletins 1 and 9 are merely administrative reports, containing no scientific matter. The other bulletins may be classified as follows:—

Geology; Bulletins 4, 6, 7, 8.
Botany; Bulletins 3, 5.
Zoölogy; Bulletin 2.

These bulletins are sold and otherwise distributed by the State Librarian. The prices are as follows: No. 1, $0.05; No. 2, .35; No. 3, .40; No. 4, .30; No. 5, .15; No. 6, .50; No. 7, .60*; No. 8, .20; No. 9, .05.

It is intended to follow a liberal policy in gratuitously distributing these publications to public libraries, colleges, and scientific institutions, and to scientific men, teachers, and others who require particular bulletins for their work, especially to those who are citizens of Connecticut.

Applications or inquiries should be addressed to

GEORGE S. GODARD,
State Librarian,
Hartford, Conn.

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* If map is mounted as a wall map, and sen ress, $1.60.

CATALOGUE SLIP.

Connecticut. *State geological and natural history survey.*
... Bulletin no. 9. Second biennial report of the commissioners of the state geological and natural history survey, 1905–1906. Hartford, 1906.

23 pp., 23^{cm}.

[Administrative report, containing no scientific matter.]

State of Connecticut

PUBLIC DOCUMENT No. 47

State Geological and Natural History Survey

COMMISSIONERS

HENRY ROBERTS, Governor of Connecticut (*Chairman*)
ARTHUR TWINING HADLEY, President of Yale University
BRADFORD PAUL RAYMOND, President of Wesleyan University
FLAVEL SWEETEN LUTHER, President of Trinity College (*Secretary*)
RUFUS WHITTAKER STIMSON, President of Connecticut Agricultural College

SUPERINTENDENT
WILLIAM NORTH RICE

BULLETIN No. 9

HARTFORD PRESS
The Case, Lockwood & Brainard Company
1906

SECOND BIENNIAL REPORT OF THE COMMISSIONERS

OF THE

State Geological and Natural History Survey of Connecticut

1905-1906

HARTFORD PRESS:
The Case, Lockwood & Brainard Company.
1906

HARTFORD, CONN., December 26, 1906.

HIS EXCELLENCY, HENRY ROBERTS, Governor of Connecticut,
Hartford, Connecticut.

Sir: — I have the honor to transmit to you herewith, in behalf of the Connecticut Geological and Natural History Survey Commission, the report of the Superintendent of the work, covering the period of two years ending December 31, 1906.

Very respectfully,
FLAVEL S. LUTHER,
Secretary of the Commission.

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY.

SECOND BIENNIAL REPORT.

SCOPE AND PLAN OF THE SURVEY.

In this second report it may be convenient briefly to recapitulate what was more fully stated in the first report in regard to the aims of the Survey and the plan of organization which has been adopted. The act establishing the Survey was approved June 3, 1903. The title given to the Survey in that act, and the more explicit language of section 2 of the act, present to the Survey two subjects for investigation; viz., the geology of the state, and the natural history, or botany and zoology, of the state. While no specific directions are given in the law as to the proportionate amounts of time and money to be expended upon the various objects of study, it has been assumed as a fair interpretation of the spirit and intent of the law that geology and biology should receive not far from equal shares of the appropriation. The law establishing the Survey further sets before us three aims to be regarded in the studies undertaken and in the mode of publication of their results:—first, the advancement of our knowledge of the botany, zoology, and geology of the state, as a matter of pure science; second, the advancement of the economic interests of the state by the acquisition and publication of the knowledge of its resources; third, the promotion of the educational work of the schools of the state by the publication of the results of investigation in such form as will be adapted for the use of teachers. We have planned the work of the Survey with the purpose of accomplishing these three objects as far as our limited means would allow.

The plan of organization, of which an account was given in the first report, has been retained. Only one salaried officer has been appointed by the Commissioners; viz., the Superintendent. Other scientific men have been engaged to investigate particular subjects and to prepare reports or bulletins thereon. In the great majority of cases the terms of contract with these scientific men have been that the investigator should receive a certain sum as compensation when the bulletin presented was accepted by the Superintendent, and that a certain allowance should also be made from the appropriation for the Survey for the expenses of the work, the allotment for expenses to be drawn upon from time to time as the expenses were actually incurred. In a few cases scientific men have been engaged to commence investigations which they were not expected to finish within the current biennial term; in which cases the compensation offered has been regulated by the amount of time which was to be spent in these preliminary investigations.

Each report prepared is published as a separate bulletin, the bulletins being numbered consecutively, generally in the order of time in which they are received. Each bulletin bears the name of the author or the names of the authors, and each author is responsible for his own work. The bulletins are issued in paper covers, but a part of the edition is reserved for binding. From time to time the bulletins which have been published will be collected for binding in volumes generally of not less than 500 pages nor more than 1000. The publications of the Survey are distributed by the State Librarian. They are given liberally to colleges, public libraries, geological surveys, and other scientific institutions, and to scientific men of repute in the branches of science with which the respective bulletins are concerned. In many cases publications of great value are received in exchange for the publications of the Survey. All books and papers thus received in exchange are deposited in the State Library. The publications of the Survey are also distributed liberally

to citizens of our own state. In the case of persons in other states who are not known as scientific men, and who appear to have no special claim for the donation of the publications of the Survey, the bulletins are sold at prices sufficient to cover the cost of printing and binding.

BULLETINS ALREADY PUBLISHED.

The First Biennial Report of the Commissioners is numbered in the consecutive series as Bulletin No. 1. Since the presentation of that report four other bulletins have been published as follows:—

No. 2. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut; by Herbert William Conn.

No. 3. A Preliminary Report on the Hymeniales of Connecticut; by Edward Albert White.

No. 4. The Clays and Clay Industries of Connecticut; by Gerald Francis Loughlin.

No. 5. The Ustilagineæ, or Smuts, of Connecticut; by George Perkins Clinton.

These reports have received high commendation from scientific journals and from the newspaper press of our own and other states, and it is believed that they record important accessions to the useful knowledge of the natural history and resources of our state.

Professor Conn's Report on the Protozoa of our Fresh Waters is illustrated by thirty-four plates made from drawings by his own hand. This bulletin is of great utility in an educational point of view, since most of the literature dealing with the protozoa is not readily accessible to the teachers in our high schools and to students who may wish to study the minute life of Connecticut fresh waters.

Professor White's Report on the Hymeniales deals with a group of relatively large and conspicuous fungi, which are of economic importance because some of them are edible and others are extremely poisonous. The report is illustrated with forty plates mostly from exquisite photographs taken by Professor White himself. Within the last few years a great interest has been awakened in the

subject of fungi, particularly with reference to their edible qualities, and Professor White's work has therefore responded to a popular demand.

Dr. Loughlin's paper on the Clays and Clay Industries of the state is a valuable contribution both from the standpoint of pure science and from that of the economic application of science. It discusses the distribution of our Connecticut clays and the geological conditions under which they were formed, and their physical and chemical properties, and treats very fully of their uses in the manufacture of brick and pottery.

Dr. Clinton's Report on the Smuts deals with a group of microscopic parasitic fungi whose economic importance is very great on account of the destruction of agricultural products which they cause. It has been estimated that in Illinois an average loss of oats alone to the value of $1,000,000 is caused by two species of these parasitic fungi. Dr. Clinton's investigation has been thorough and elaborate, and his brief paper is of high scientific and economic value.

BULLETINS ACCEPTED FOR PUBLICATION.

Three bulletins have been accepted for publication, two of which are already in type. These are the following:—
No. 6. Manual of the Geology of Connecticut; by William North Rice, Professor of Geology in Wesleyan University, and Herbert Ernest Gregory, Professor of Geology in Yale University.

No. 7. Preliminary Geological Map of Connecticut; by Herbert Ernest Gregory, and Henry Hollister Robinson, Instructor in Geology in Yale University.

No. 8. Bibliography of Connecticut Geology; by Herbert Ernest Gregory.

The Manual of Geology will be the first publication which has aimed to give a somewhat detailed account of the geology of the entire state of Connecticut since the publication of Percival's report in 1842. It is needless to say that our knowledge of the subject has greatly advanced within that period of almost two-thirds of a century. Much

has been done in the study of Connecticut geology in the field by officers of the U. S. Geological Survey and by private individuals, and the general advance of dynamical geology has put a new interpretation upon facts previously known. But the results of the new work on Connecticut geology, so far as they have been published, are scattered through numerous volumes of official reports, scientific journals, and proceedings of learned societies, so as to be inaccessible to those who are not within reach of large libraries or who have not acquired the difficult art of searching through numerous reports and serials for the scattered treasures buried therein. Especially for the teachers in our state it is believed that the Manual of Geology will meet a long felt want.

The Geological Map of Connecticut is on a scale of four miles to the inch. It is to be produced by chromolithography in the establishment of Julius Bien & Co. The map will be accompanied by a brief pamphlet giving a historical sketch of the geological investigations which have furnished the data, with all necessary explanations of the map itself. The map is to be issued in three different forms:—the first, printed on thin paper, folded and inserted in the pamphlet; the second, printed on thick paper, rolled, and forwarded in a pasteboard tube; the third, mounted on cloth and provided with rollers for use as a wall map. Those persons and institutions who choose to receive the map in one of the two latter forms, which are, of course, more expensive than the first, will pay the difference in cost. It is hoped that a copy of this map will soon be displayed in every high school in the state.

The Bibliography of Connecticut Geology has been compiled with much labor and care by Professor Gregory. It gives not only the titles, but also a brief analysis of the contents, of all important publications relating to Connecticut geology, whether appearing as independent works or as articles in government reports or in scientific serials. An account is also given of maps in which the geology of the entire state or of parts of the state is shown. It is

believed that all students of the geology of the state will find this bulletin very useful.

WORK STILL IN PROGRESS.

The investigations still in progress may be described under the three heads, geology, botany, and zoology.

I. Geology.

Professor Joseph Barrell, of Yale University, has been engaged, with the assistance of Dr. G. F. Loughlin, on a paper on the rocks of Connecticut. This paper will describe all the important lithological types represented in Connecticut, giving their chemical and mineralogical constitution, their appearance to the naked eye, and somewhat in regard to their aspect when studied in thin sections under the microscope. Special attention will be given to those rocks which are useful as building stones or as ornamental stones. This bulletin will be illustrated by suites of specimens of the rocks of Connecticut which have been collected under the direction of Professor Barrell. One of these suites of specimens will be given to each of the colleges, normal schools, and important high schools and academies of the state, on the simple condition of payment of the expense of transportation. Such a suite of typical Connecticut rocks, with the bulletin describing the same in language no more technical than is absolutely necessary, will be, it is believed, of very great educational value.

F. P. Gulliver, Ph.D., of Norwich, is engaged in a detailed and elaborate study of the terraces of the Thames estuary. This paper, it is expected, will be a valuable contribution to geological science. Recent studies have shown that in all probability some of the river terraces, particularly in the lower or estuarine parts of the rivers, were not formed, as has been commonly assumed, after the retreat of the ice sheet of the Glacial period from the valley or portion of valley in which they are situated, but are rather in the nature of delta deposits formed by the water flowing out from tongues of the glacier which projected

into the valleys after the ice had receded from the higher ground adjacent. The work of Dr. Gulliver on the terraces of the Thames is an example of a kind of work which should be done on other rivers.

Professor H. E. Gregory, of Yale University, has commenced a general study of the Quaternary geology of the state. In the geological map which is soon to be published the Quaternary is entirely omitted. It is hoped that it may be practicable at no very distant date to construct a map of the Quaternary deposits of the state, perhaps on the same scale as the map of the older formations now being published. It is not expected that Professor Gregory's work will be sufficiently advanced to be embodied in a bulletin within the present biennial term; but, if an appropriation shall be made for the next biennial term, his work will doubtless be continued, and will result in the preparation of an important bulletin.

II. Botany.

The Connecticut Botanical Society has nearly finished an annotated list of the flowering plants and the highest group of the flowerless plants (phanerogams and pteridophytes) of the state. This list represents a large amount of labor contributed by a large number of earnest workers. It will be a valuable contribution to science, and especially useful to the teachers of the state.

Professor Alexander W. Evans and Mr. George E. Nichols, of Yale University, have been engaged for some time on a paper on the mosses and liverworts (bryophytes) of the state. Their work is nearly ready for publication, and will be issued as a bulletin. It will be a valuable contribution to our knowledge of that group of plants.

Professor E. A. White, of the Connecticut Agricultural College, has continued his study of the fleshy fungi, on which he presented a preliminary report, published as Bulletin No. 3. A second bulletin, which he is expected to have ready for publication at an early date, will present the result of a more detailed study of the family Agaricaceæ.

Special attention will be given in this paper to the full description of the edible species of the group.

George P. Clinton, Sc.D., of the Agricultural Experiment Station, New Haven, whose paper on the smuts was published as Bulletin No. 5, is at work on another important group of parasitic fungi; viz., the downy mildews. This group includes a number of parasites destructive to important agricultural products, and will be therefore an important contribution to the economic botany of the state.

Professor H. W. Conn, of Wesleyan University, is continuing his study of the microscopic life of our fresh waters and particularly of our reservoirs. He has already published as Bulletin No. 2 of this Survey a report on the protozoa of these waters. A paper on the fresh-water algæ, by Professor Conn and Mrs. L. W. Webster, is well advanced towards completion, and will doubtless be presented for publication at an early date. Investigations of the bacteria of our fresh waters are also in progress in Professor Conn's laboratory, but it is not expected that the work on that group will be so far advanced as to be published within the present biennial term.

III. Zoology.

Mr. John H. Sage, of Portland, and Dr. Louis B. Bishop, of New Haven, are at work upon a very elaborate and valuable paper on the birds of Connecticut. Their bulletin will not contain descriptions of the birds, since good manuals of the ornithology of this part of the country are readily accessible. The work of Messrs. Sage and Bishop will contain an immense amount of information in regard to the date of arrival and departure of our migratory birds, the localities of rare birds, and the food and habits of the birds. This bulletin will be of very great importance, both economically and educationally. A large edition will be printed, and its wide distribution will be of great utility.

W. E. Britton, Ph.D., of the Agricultural Experiment Station, New Haven, with the assistance of Messrs. H. L. Viereck and B. H. Walden and other collaborators, is pre-

paring reports on two important groups of insects, viz., the hymenoptera and the orthoptera. These bulletins will contain analytical keys for the identification of the genera and species, and will also treat of the economic relations of the insects of these groups. Many of the insects of these groups are notably useful or injurious; and these reports of Dr. Britton will be important contributions in all three of the lines to which the work of the Survey is directed: the scientific, the economic, and the educational.

Professor Wesley R. Coe, of Yale University, is preparing a paper on the small but exceedingly interesting group of echinoderms. The star-fishes, which are among the best-known representatives of this group, occasion a very serious loss to the resources of the state by the ravages which they make in oyster beds; and, apart from the purely scientific aspect of the group, Professor Coe has given much attention to their economic relations. This paper on echinoderms, it is hoped, will be the beginning of a series of papers by various authors on the various groups of marine animals on our coast.

DISTRIBUTION OF THE APPROPRIATIONS.

The payments for the work already completed have been as follows:—

Name	Work		Compensation	Expenses
W. N. Rice, ...	Superintendence,	1903-5,	$400	$189.41
H. W. Conn, ...	Bulletin No. 2,	. .	400	198.73
E. A. White, ...	" " 3,	. .	150	88.68
G. F. Loughlin, ...	" " 4,	. .	30	9.03
G. P. Clinton, ...	" " 5,	. .	50	8.20
H. E. Gregory, ...	" " 6,	. .	150	250.00
H. E. Gregory and H. H. Robinson, ...	" " 7,	. .	450	

In several of these cases the payments on account of expenses have been much less than the amounts allotted.

The allotments for work now in progress are as follows:—

Name	Work	Compensation	Expenses
W. N. Rice, . . .	Superintendence, 1905-7,	$400	$300
J. Barrell, ...	Rocks, ...	150	550
F. P. Gulliver, . . .	Terraces of Thames River, ...	100	150
H. E. Gregory, . . .	Quaternary Geology, .	200	150
Conn. Botanical Society, .	Phanerogams and Pteridophytes, . . .	0	100
A. W. Evans and G. E. Nichols, ...	Bryophytes, . . .	100	50
E. A. White, . . .	Agaricaceæ, . . .	100	75
G. P. Clinton, . . .	Downy Mildews, . .	50	25
H. W. Conn, . . .	Algæ and Bacteria of fresh water, . .	150	250
J. H. Sage and L. B. Bishop, . . .	Birds, ...	200	200
W. E. Britton, . . .	Hymenoptera and Orthoptera, . . .	125	75
W. R. Coe, . . .	Echinoderms, . .	75	25

The fact will be noted that the compensation is in all cases very small in relation to the amount of work done and the grade of ability and attainment of the scientific men employed. The work has been indeed on the part of all who have been engaged in it a labor of love.

LEGISLATION DESIRED IN REGARD TO PUBLICATION OF THE REPORTS OF THE SURVEY.

In our first Biennial Report attention was called to the fact that the general law of the state allows only 1375 copies of any official report to be printed, and that such an edition is altogether inadequate for the bulletins of the Survey. It is desired that the bulletins of our Survey should be, as is customary in other states, widely distributed to colleges, scientific institutions, public libraries, scientific men, teachers, and others. The editions of similar reports published by other states are never less than 1500, and generally range from 3000 to 8000. In our former report we recommended that 3000 copies of the Biennial Report, 4500 of the Manual of Connecticut Geology and the report of Messrs. Sage and Bishop on Birds, and 3500 of the other

bulletins then in preparation, should be printed. At the last session of the General Assembly a resolution was adopted authorizing the printing of the desired number of copies of so many of the bulletins as should be ready for printing before January 1, 1907. As the authorization granted by this resolution lapses before the beginning of the ensuing session of the General Assembly, it is necessary for us now to request the General Assembly to authorize the printing of editions of the bulletins to be published in the near future larger than is permitted by the general law. As is apparent from what has already been said, the bulletins which will soon be issued present much variety of contents, some of them being of a more popular character and appealing to a larger constituency than others. The respective numbers of copies of the bulletins to be published in the near future, necessary to meet the demand which may be reasonably anticipated, are as follows:—

Author	Subject	No. of Copies
H. E. Gregory,	Bibliography of Connecticut Geology,	3000
J. Barrell,	Rocks of Connecticut,	3500
F. P. Gulliver,	Terraces of Thames River,	3000
Conn. Botanical Society,	Flora of Connecticut,	4000
A. W. Evans,	Mosses and Liverworts,	3000
E. A. White,	Fleshy Fungi,	3500
G. P. Clinton,	Downy Mildews,	3000
H. W. Conn,	Fresh-water Algæ,	3500
J. H. Sage and L. B. Bishop,	Birds of Connecticut,	4500
W. E. Britton,	Orthoptera and Hymenoptera,	3500
W. R. Coe,	Echinoderms,	3500

We accordingly respectfully recommend that a number of copies of each of the above named bulletins may be authorized to be printed, in addition to the 1375 copies prescribed by the general law, sufficient to amount to the numbers above specified.

PLANS FOR FUTURE WORK.

I. Geology.

It may be said in general that much more of detailed work will be required than has yet been given to many parts of the state. The Manual of Geology and the Geological Map which are now in press must be considered as reports of progress and not as final reports upon the geology of the state. It has been deemed wise to publish these two bulletins as representing the present state of our knowledge, rather than to wait an indefinite period for the correction of all errors and the supplementing of all deficiences. But the geological work which has been done in some parts of the state is little more than reconnoissance. This is especially true of the crystalline rocks of eastern Connecticut. It is possible that the prosecution of detailed work in the field may bring to light facts which will lead to important changes in our general conception of the geological history which those rocks represent.

In the important department of glacial geology, only a beginning has been made. Much of the work which has been done in the study of terraces and other Quaternary formations has been largely vitiated by theoretical notions now believed to be erroneous. Evidently a large amount of work must be done before the Glacial and post-Glacial history of our state can be understood. The detailed investigation by Dr. Gulliver in regard to the terraces of the Thames estuary is an example of the kind of work which needs to be done in other localities. Professor Gregory has made a beginning of a general study of the Quaternary formations of the state; but a large amount of work must be done before any satisfactory map of our Quaternary formations can be prepared.

A report on the mineralogy of our state would be very useful. A simple list of minerals found in the different towns of the state has, indeed, been published in Dana's standard works on Mineralogy; but a report on the mineralogy of the state should give a somewhat detailed description of the important mineral localities, illustrated,

when necessary, by sketch maps; and should also treat of the geological relations of the various minerals.

Another subject on which a bulletin would be desirable is the fossil fishes of the Triassic formation. Our knowledge of fossil fishes in general has advanced considerably since the publication of Newberry's Fossil Fishes of the Triassic (Monograph No. 14 of the United States Geological Survey). Extensive collections of the fossil fishes of Connecticut are to be found in the museums of Yale and Wesleyan, and also in possession of the United States Geological Survey; and a monograph written in the light of most recent knowledge would be very desirable.

The work of the United States Geological Survey in testing the fuel value of various mineral hydrocarbons has awakened great public interest in the deposits of peat. It has long been known in a vague and general way that Connecticut, like all other regions in which the preëxistent drainage was disturbed by the ice sheet of the Glacial period, possesses extensive deposits of peat; but nothing is definitely known in regard to the area, or depth, or quality of the peat deposits of Connecticut. An investigation which should be undertaken at an early date, is a detailed survey of the peat deposits of Connecticut. Such an investigation may result in the revelation of an important item of our resources.

II. Botany.

It is unnecessary for the State Survey to publish a manual giving descriptions of flowering plants or of ferns and their allies, since there are books readily accessible to the public that treat in a full and satisfactory way the systematic botany of the higher groups of plants. An investigation which the State Survey might appropriately undertake would be the study of the distribution of plants with reference to altitude, geological formation, distance from the sea, temperature, and rain-fall, and the grouping of plants into plant societies in different areas — in short, the study of what is now called the ecology of plants.

While there is no lack of works accessible to the public on the phanerogams and the higher cryptogams, the case is very different with the lower cryptogams, to which, in general, much less attention has been given. The work of Professor White on some of the groups of large and conspicuous fungi, of Dr. Clinton on some of the microscopic parasitic fungi, and of Professor Conn on the fresh-water algæ and bacteria, is a good beginning; but much work remains to be done in that field.

III. Zoology.

One of the plans which were discussed among those who were interested in the establishment of a State Natural History Survey, even before the organization of the Survey was effected, was that of making a complete study of the life, and particularly of the minute life, of our fresh waters, both in the interest of pure science, and in the thought of possible economic results from the knowledge of distribution of organisms in reservoirs and other sources of the water supply of the community. In accordance with this general plan, Professor Conn is engaged in the study of the protozoa, algæ, and bacteria of our fresh waters. This study should be extended to include all the other groups of organisms living in our fresh waters. A thorough study, for instance, of the minute crustacea that abound in our fresh waters, would be interesting and valuable.

Dr. Britton and his collaborators will soon have ready for publication elaborate and important papers on two groups of insects, the hymenoptera and the orthoptera. There are, however, other groups of insects, more numerous than these, including larger numbers of species economically important for the good or the evil which they do to agricultural interests. It is obviously desirable that, in the near future, similar studies should be made of other groups of insects.

Connecticut has a long coast line and a varied marine fauna, including a number of useful species and some very decidedly injurious ones. Practically nothing has been

published on the marine invertebrate fauna of our coast, with the exception of descriptions of particular species and other papers on technical details, since the paper by Verrill and Smith on the Invertebrate Animals of Vineyard Sound, published in the report of the United States Commissioner of Fish and Fisheries for 1871-2. A series of papers on the various groups of marine animals, with analytical keys to families and genera, and with due notice of those species whose utility or injuriousness makes them of economic importance, would be invaluable to teachers, and might also be of considerable utility to the fisheries of the state.

THE NEED OF FURTHER APPROPRIATIONS.

While it is believed that the investigations which have been undertaken under the auspices of the State Survey, and the publications in which the results of these investigations have been or will be embodied, are important scientifically, educationally, and economically, it is at once obvious that the work completed or in progress is only a very small part of the work which may appropriately be done by such a Survey. If it was wise to establish a State Survey in 1903, it is wise now to continue it and provide the necessary appropriation for its maintenance.

Many of the other states are carrying on at the present time geological surveys on a much larger scale than that of our own state. For instance, North Carolina, Wisconsin, and New Jersey have been appropriating in recent years $10,000 annually for the work of their geological surveys, exclusive of the cost of publication. Maryland appropriates $10,000 a year for its geological survey, inclusive of the cost of publication, but exclusive of much larger appropriations for topographical work and improvement of highways. Alabama appropriates $7,500 per year; Ohio, $2,900; Michigan, $8,000; Indiana, $7,620; Vermont, $1,550; West Virginia, $7,000; Georgia, $8,000. Kansas appropriates $3,000 for its geological survey, exclusive of the salary of the director. All of these appropriations (except that of Maryland) are exclusive of the cost of publication of the results

of the survey. Most of these appropriations, moreover, are for geology alone. Ohio is agitating for the establishment of a natural history survey, in addition to its geological survey. The comparison with other states makes it obvious that, in the appropriation of $3,000 for the biennial term, Connecticut is not erring in the direction of too lavish expenditure.*

The history of the state surveys in other states shows a differentiation, more or less definite, of surveys that have been established, into two classes. In some instances, appropriations have been made, generally somewhat liberal in amount, for a very short term of years, in the expectation that final reports on all the subjects treated should be published, and the survey should be discontinued. In other cases, the plan of annual appropriations has been followed, often comparatively small in amount, continuing somewhat permanently. The state of New York, for instance, though it has at present no institution bearing the title of State Geological Survey, has been maintaining geological and biological investigations and publishing reports of the same almost continuously for more than sixty years. There is certainly much to be said in favor of the plan of moderate appropriations continued permanently, as contrasted with the plan of large appropriations for a few years. In the nature of the case, it is impossible that the study of the geology or the biology of a state should ever be exhausted. The advance of science, while it solves some problems, suggests new ones. The changes which are being made continually in the processes of arts and manufactures bring into use from time to time new forms of raw material and create a demand therefor. The study of the products and resources of any area, whether from the scientific or from the economic standpoint, takes on from time to time new meanings with the progress of science and art.

If, then, final reports are issued and a survey discontinued, a new survey is imperatively demanded after a

* The numerical statements in this paragraph were obtained in 1905. There may have been changes in the amount of the appropriations by more recent legislation in some of the states.

lapse of not many years. A survey continued as a permanent institution with a moderate appropriation each year is able to do its work economically, in that it can largely employ the services of teachers in colleges and other institutions and to some extent of amateur scientists, who are willing to work in vacations or at odd times for merely nominal compensation. If, on the other hand, a survey is to be hurried up and final reports produced within a period of a very few years, a considerable corps of scientific workers must be engaged, and salaries paid which will command substantially their whole time. A permanent survey can adjust its work from time to time to special conditions, both of supply and demand. It can avail itself of important investigations which have been commenced by various scientists within or without the state, and thus afford a medium for the publication of researches of importance which might otherwise remain long unpublished. It can turn its attention from time to time to particular natural products in which popular interest may be excited, as, for instance, in the case of peat deposits at the present time. Its work may thus have an added value, dependent upon its timeliness. It can revise and correct its own work when the progress of science demands it, by the publication of supplementary reports.

It is not probable that the state of Connecticut will make at present any large appropriation for the State Survey. It should certainly provide for the continuance of a moderate appropriation, and it would seem entirely reasonable that there should be some increase of the very small appropriation which has been made for the present and the previous biennial term.

CATALOGUE SLIPS.

Webster, Lucia Washburn (Hazen), and ***Conn, Herbert William.***

A preliminary report on the algæ of the fresh waters of Connecticut. By Herbert William Conn and Lucia Washburn (Hazen) Webster. Hartford, 1908.

78 pp., 44 pls., 23^{cm}.

(Bulletin no. 10, Connecticut geological and natural history survey.)

Botany.

Conn, H. W., and Webster, L. W. A preliminary report on the algæ of the fresh waters of Connecticut. Hartford, 1908.

78 pp., 44 pls., 23^{cm}.

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State of Connecticut

PUBLIC DOCUMENT No. 47

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BULLETIN No. 10

HARTFORD
Printed for the State Geological and Natural History Survey
1908

A PRELIMINARY REPORT

ON

THE ALGÆ OF THE FRESH WATERS OF CONNECTICUT

By

HERBERT WILLIAM CONN, Ph.D.,

Professor of Biology in Wesleyan University

AND

LUCIA WASHBURN (HAZEN) WEBSTER, M.S.

HARTFORD

Printed for the State Geological and Natural History Survey

1908

A Preliminary Report on the Algæ of the Fresh Waters of Connecticut.

INTRODUCTION.

The present report is designed to accompany the previous report upon the Fresh-water Protozoa, Bulletin No. 2 of this Survey. Like that report, it is not claimed to be complete, nor by any means to contain all of our Algæ. But, the work having covered considerable parts of four years, it is thought that it will be found to contain most of the common Algæ in this state, and will therefore be useful as a guide to students of the microscopy of our waters. To wait until all omissions could be filled would clearly postpone unduly the publication of any report. For these reasons this preliminary report is issued at the present time.

Work upon the Algæ is scattered somewhat widely in books and in journals. We have found most valuable, *The British Fresh-water Algæ,* by West. Wolle's *Fresh-water Algæ of the United States,* and his similar work on the Desmids, have also been found extremely useful. The magnificent work of Engler and Prantl has been found of great value, as has also *Die Mikroskopische Pflanzenwelt des Süsswassers* by Kirchner, and the *Analytical Keys of Genera and Species of the Fresh-water Algæ* by Stokes. The most useful publication upon a single group has been that of Hazen — *The Ulotrichaceæ and Chætophoraceæ,* in the Memoirs of the Torrey Botanical Club, XXII, 1902.

The key that we have adopted in this Bulletin is based upon that given by West. We have used this because in our experience it has been found to be the most practical and useful. We have, however, modified it in several respects to make it correspond to the key used in the Bulletin on the Protozoa. As so modified, we think it will be found very easy of use for microscopists who are beginning the study of the Algæ.

We have adopted the plan used in the Bulletin on the Protozoa of indicating by a * in the analytical keys the genera that have been found in our waters. In a number of cases the genera thus indicated have not yet been found by ourselves, although known to occur in Connecticut. We have given descriptions of all the genera likely to be found in this vicinity, whether already known to occur in Connecticut or not.

So far as possible we have determined the species of the forms studied and figured. While there is considerable variation among the individuals of the same species of Algæ, it is less than among the Protozoa, and it is less difficult to determine species. In most cases there has been little difficulty in affixing specific as well as generic names to the Algæ found. In some genera the determination of species is nearly impossible without the whole life history of the specimen under consideration. In the genus *Spirogyra*, for instance, the species are determined with certainty only when one has the zygospores for study. The ordinary student of Algæ is seldom so fortunate as to have the zygospores, and must in these cases make his determination from other characters. We have, therefore, in these cases determined the species as well as possible from the general structure of the plant, thinking this to be more practical than to rely upon the more rarely seen zygospores.

The figures have all been drawn from nature, and all from specimens found by ourselves in our waters. A majority of them have come from the immediate vicinity of Middletown. Collections have been made from other parts of the state, but these other localities have not yet yielded many forms not represented in this immediate vicinity. The Algæ have not been to a very large extent obtained from city reservoirs, since these localities are not very profuse in this kind of life. Roadside pools, ditches by railroads, swamps, stagnant pools, etc., have been more prolific sources of Algæ.

The late Isaac Holden made during his life large collections of Algæ in the state. The largest number of the types that he collected were marine, but he also made quite extensive collections of the fresh-water forms. A list of the species identified by him in this state has been recently published by

F. S. Collins (*Phycological Notes of Isaac Holden*, in *Rhodora*, vol. 7, p. 222, 1905). Since he identified quite a number of species that we have not found, we have, for the purpose of making this report as complete as possible, included in this list all the species reported by him which we have not ourselves identified. These have been appended to our own list, and are distinguished by being inclosed in square brackets [ ]. We have not given any figures of his species, however, all of the species figured having been personally found by ourselves. In a few cases we have noted the collection of certain species in this state by Hazen and by Setchell. No other extensive collections of Algæ are known to us as having been made in the state.

The figures of plates I to XXXI were drawn by Mrs. Webster, except figures 5, 8, 8*a*, 10, 28, 31, 45, 47, 49, 54, 54*a*, 55, 57, 59, 65, 72, 72*a*, 73, 77, 77*a*, 102, 125, and 147. These together with the figures of Plates XXXII to XLIV were drawn by Prof. Conn. Acknowledgment is also made to H. J. Conn from whose work and sketches many of the figures of Plates XXXII to XLIV have been drawn.

THE ALGÆ.

The ALGÆ are flowerless chlorophyll-bearing water plants. Although sometimes called seaweeds, they are not confined to salt water, but are found in every body of fresh water, on damp stones and soil, and on the trunks of trees. They are, however, all true water plants, for the few that live out of water can flourish only in the presence of abundant moisture.

The Algæ show the widest variety in form, size, and structure. They may be unicellular or multicellular; they may be solitary, or gathered into larger or smaller families; they may grow in all directions to form a spherical thallus, or into plates only one cell thick, or into branched or unbranched filaments. When multicellular, all the cells may be alike, or there may be a differentiation of cells, apical and root cells, vegetative and sexual cells being found. The filamentous thallus may present the appearance of a highly developed plant, as in the Rhodophyceæ or Characeæ, or may be a single simple thread, as in the Zygnemaceæ.

The coloring matter of the Algæ, either diffused throughout the cell wall, or aggregated in special bodies called *chloroplasts,* is predominantly green; but there is hardly any color known which cannot be found in these plants, the colors running from orange and red to purple and black. Their size differs as greatly as their color; some are so small as to test the best microscopes, while others stretch two hundred feet from their marine beds.

The Algæ multiply both by the sexual and the asexual method. The asexual method is universal, the sexual is more uncommon. They reproduce asexually in three ways:— 1, By *simple division* of the mother-cell. In the multicellular forms a small fragment or a branch may separate from the mother plant to form a new one. 2, By means of *spores,* which are formed from the contents of the vegetative cells, and which have each a cell wall, and may or may not be motile. 3,

By *swarm spores,* which lack cell walls and are always motile, usually provided with cilia. The sexual reproduction is of two kinds:— 1, *Conjugation,* or the union of two similar or nearly similar cells called *isogamous gametes.* These may be either motile cells, as in *Ulothrix,* or cells of the thallus, as in the Conjugatæ. They join themselves together, and their contents fuse to form a new cell, a *zygote,* which, after a short period of rest, develops into a new plant. 2, *Sex union* proper, or the union of two entirely different cells, one of which, the male or sperm, is many times smaller than the other, the female or egg — *heterogamous gametes.* This occurs, for example, in *Chara.*

The Algæ are found from the Arctic zone to the Equator, and no genus is confined to a single latitude. We should sadly miss these plants if they were all destroyed. They do much to purify the atmosphere, are used to a considerable extent in medicine, provide food for fishes and for men, fodder for cattle, and fertilization for the ground.

The Algæ are divided into classes as follows:—

CLASS I. CYANOPHYCEÆ (Schizophyceæ, Myxophyceæ, or Blue-green Algæ). Containing a blue coloring matter (phycocyanin). Mostly in fresh water, and simple in structure.

CLASS II. BACILLARIEÆ (Diatomaceæ). Containing a brown coloring matter (diatomin). Universal both in fresh and salt water.

CLASS III. HETEROKONTÆ (Yellow-green Algæ). Containing a large amount of a yellow pigment (xanthophyll). The stored product of assimilation is a fatty substance. Found in fresh water.

CLASS IV. CHLOROPHYCEÆ (Green Algæ). Containing only the green coloring matter known as chlorophyll. The product of assimilation is starch. Very largely fresh-water plants.

CLASS V. CHARACEÆ. Having a stem with nodes and internodes. Sexual reproduction.

CLASS VI. PHÆOPHYCEÆ (Brown Algæ). Containing a brown coloring matter, known as phycophæin. Mostly marine.

CLASS VII. RHODOPHYCEÆ (Red Algæ). Containing a reddish coloring matter known as phycoerythrin. Mostly marine.

In the study of the fresh-water Algæ we are concerned chiefly with the first five of these classes, the other two being practically confined to salt water, although a few of them, as noted at the end of this report, are inhabitants of fresh water.

CLASS I. CYANOPHYCEÆ.

(Myxophyceæ, Schizophyceæ, or Blue-green Algæ).

The class Cyanophyceæ is unquestionably the lowest class of the Algæ, many of the species resembling the Bacteria. Their most conspicuous characteristic is the manner in which the greater number of the genera grow in gelatinous masses or strata. They are largely filamentous, though some are unicellular. Some of them grow wherever there is moisture, as on wet rocks, stones, and trunks of trees. Some of the filamentous genera form thick, felt-like coverings upon moist earth and stones. Many of the Cyanophyceæ are provided with heterocysts, which are cells of lighter color and often of greater size than the other cells of the filament. The heterocysts are almost always solitary on the filaments, and their use is not known.

The unicellular and simple colonial genera multiply principally by repeated cell-division, which may occur in every direction or in certain directions only. Asexual reproduction of the large forms takes place in a variety of ways. In some families certain vegetative cells enlarge and form spores; in others the contents of the cells divide into a number of small spores. The Hormogoneæ reproduce by *hormogones*. These are short filaments arising from the mother plant, which break away and form new plants. Sexual reproduction is unknown.

Some of the Cyanophyceæ unite with Fungi to form Lichens, in which case they lose much of their distinctive character.

A few of the Cyanophyceæ, of the family Oscillatoriaceæ, are distinguished for their power of spontaneous movement, which is generally slow, oscillating or gliding. Many of this

family have a disagreeable odor, giving rise to unpleasant odors and tastes in drinking-water.

There are two orders, as follows:—

ORDER I. COCCOGONEÆ. Plants unicellular or colonial, not truly filamentous; commonly embedded in a gelatinous matrix, more rarely free-floating.

ORDER II. HORMOGONEÆ. Plants filamentous; filaments single or branched, generally consisting of one or more rows of cells within a sheath, attached to a substratum, or free-floating.

ORDER I. COCCOGONEÆ.

The Coccogoneæ, the lowest form of the Algæ, are unicellular or colonial. The colonies vary much in size and shape, and the cells, which are of various forms, are disposed in a variety of ways in the usually hyaline and structureless envelope. Multiplication is usually by simple cell division. Rounded asexual spores have been found in some species, formed inside the wall of the mother-cell.

FAMILY I. CHROOCOCCACEÆ.

This family is composed of unicellular forms of Algæ which divide and form daughter-cells; often many generations are involved in one mucilaginous envelope. The envelope varies from firm and lamellose to hyaline and diffluent. The cells often contain red, orange, or violet pigments. The members of this family have been thought to be stages of filamentous Algæ, and Wolle so regarded them; but more recent algologists give them a distinct place of their own.

Key to Genera.

1. Cell division in only one direction 2
   Cell division in two directions at right angles, forming plate-shaped or irregular masses ..*Merismopedia**
   Cell division alternate in the three directions of space 4
2. Cells with thin membrane, without a gelatinous or mucous envelope, single or hanging together in thick rows ....*Synechococcus*

Cells with thick, swollen membranes, which merge into one another and lie in a gelatinous or mucous bed 3

3. The thick membrane remains present through several generations, so that the cells are enclosed in several membranes; cells elongated ....*Glœothece*

Cell membranes fused into a structureless jelly in which the cells are arranged without order; cells slightly longer than broad..............*Aphanothece*

4. Cells at the periphery of spherical colonies 5

Cells densely aggregated in spherical, elongated, or clathrate colonies ....*Microcystis**

Colonies without definite form.................. 6

5. Cells spherical, closely and regularly arranged around a hollow sphere .... *Cœlosphærium**

Cells peripheric, sparsely scattered......*Gomphosphæria*

6. Cells enclosed in a thick membrane..........*Glœocapsa**

Cells not enclosed 7

7. Cells with thick, gelatinous, fusing membranes.... *Aphanocapsa**

Cells single or in small groups, with membranes which do not fuse.....................*Chroöcoccus**

Description of Genera.

Merismopedia Meyen.— Cells spherical, or, at time of division, oblong. Their regular method of division produces groups of 4, 8, 16, 32, 64, or 128 cells, associated in a single stratum, making a flat, freely floating, square thallus.

M. glauca (Ehrb.) Näg., Fig. 3.

M. convoluta Breb., Fig. 4.

Synechococcus Näg.— Cells cylindrical or oblong, found singly or in series of two or more; cell wall thin.

Glœothece Näg.— Cells oblong or cylindrical, with rounded ends. The cells divide into two nearly spherical daughter-cells. The colorless gelatinous tegument may contain one or often more cells, and this tegument may, in turn, be included in a larger tegument with a family.

Aphanothece Näg.— Very like *Glœothece,* with cells longer than broad; but the teguments are confluent, forming a firm gelatinous body which encloses the cells.

Microcystis Kütz. (**Polycystis** Kütz.; **Clathrocystis** Henfrey).— Numerous small cells gathered into globular, oblong or irregular families, each with a thin tegument, usually single but sometimes associated with other families, and all enclosed in a common tegument. The cells divide alternately in three directions.

M. æruginosa (Kütz.) (?), Figs. 9, 9*a*. Sometimes very abundant in reservoirs and giving an unpleasant taste to the water. Frequently thus associated with *Anabœna.*

Cœlosphærium Näg.— Thallus hollow, spherical, with numerous small spherical cells in families, or scattered at the periphery, embedded in a gelatinous stratum. Multiplication takes place by means of enlarged cells which escape and form daughter-cells, or by constriction and division of the mother-cells.

C. Kuetzingianum Näg., Fig. 7.

Gomphosphæria Kütz.— A globose, free, floating thallus, composed of wedge-shaped cells, in pairs, associated in radiating families at the periphery of a solid gelatinous sphere, and furnished with a tegument. The cells divide alternately in three directions.

Glœocapsa Kütz.— Cells blue-green, steel-blue, reddish, yellowish, etc., spherical or oblong, with a wide, bladder-shaped integument. The cells divide into two daughter-cells, each furnished with a tegument and both surrounded by the tegument of the mother-cell. The cell membrane is very thick, often lamellated, and the strata frequently separate; either colorless or colored.

G. arenaria (Rab.) (?), Figs. 8, 8*a*. The specific distinctions in this genus are very uncertain.

[*G. violacea* (Chorda) Rab.]

Aphanocapsa Näg.— Cells spherical, with a thick, soft tegument; cell division as in *Glœocapsa,* but individual coats not evident around the cell.

A. Grevillei (Hass.) Rab., Fig. 10. Masses of this jelly-like plant frequently reach 2mm. in diameter.

Chroococcus Näg.— Blue-green cells, spherical, or angular from mutual pressure, gathered into small families without a distinct tegument. The cells, which are less numerous and more simple than in *Glœocapsa,* divide alternately in three directions.

C. cohærens (Breb.) Näg., Fig. 210.

FAMILY II. CHAMÆSIPHONIACEÆ.

Not represented in the United States.

ORDER II. HORMOGONEÆ.

This order contains all the filamentous Myxophyceæ. The filaments usually consist of a single row of naked or sheathed cells, but in some genera there are two or more rows in a single sheath. Heterocysts are abundant in some of the genera. The filaments are often branched or provided with a false branch system due to the growth of a number of filaments in close apposition at the base. Asexual reproduction is by hormogones or, more rarely, by spores. The filaments or trichomes are usually cylindrical with blunt or narrowed extremities, but some genera show a gradual attenuation, either from the base to the apex, or from the centre toward each end.

This order includes two sub-orders.

SUB-ORDER I. TRICHOPHOREÆ. Trichomes conspicuously attenuated towards one or both extremities, which are generally hairy.

SUB-ORDER II. PSILONEMATEÆ. Trichomes cylindrical, though sometimes narrowed at the extremities.

SUB-ORDER I. TRICHOPHOREÆ.

A small group with the filaments always attenuated, either toward one end or from the middle to both extremities, and always sheathed. Some genera are provided with heterocysts. There is an asexual reproduction by means of hormogones, but in *Glœotrichia* the basal cells next the heterocysts develop spores. The threads frequently show hair-like projections from their sides.

FAMILY I. RIVULARIACEÆ.

Abundant in mountainous regions, found principally on dripping rocks, in streams and waterfalls, or on the shores of rocky lakes. Our collections not having included such localities, this family is not represented in our figures. The filaments are all attenuated from a long base to a hair-like end. One or two heterocysts are usually located at the base. The sheath is yellow or yellowish-brown, gelatinous, tubular, and often thoroughly lamellated. Asexual reproduction by hormogones, and in *Glœotrichia* and *Calothrix* asexual spores arise near the basal heterocysts.

Key to Genera.

1. Without heterocysts . . . . *Amphithrix**
   With heterocysts 2
2. Filaments without gelatinous integument, simple, growing in branched or unbranched tufts, or sometimes singly . . . . *Calothrix**
   Filaments without gelatinous integument, branched, several branches in a common sheath . . . . *Dichothrix**
   Filaments with a gelatinous integument, forming a gelatinous or mucous covering 3
3. Filaments radially disposed; thallus spherical or hemispherical in shape 4
   Filaments not radiating; thallus plain, cushion-shaped . . . . *Isactis*
4. Spores present; single-celled or with heterocysts; colonies free, floating . . . . *Glœotrichia**
   Spores lacking; colonies attached . . . . *Rivularia**

Description of Genera.

Amphithrix Kütz.— The filaments form a thin expanded stratum of a purple or violet color, which consists of two layers. The inferior layer is composed of densely intricate filaments, or of minute radiately disposed series of cells; the superior layer of simple erect filaments closely packed and attenuated.

[*A. janthina* (Mont.) Born. and Flah.]

Calothrix Ag. (**Mastigonema** Schwabe; **Mastigothrix** Kütz., in part).— Filaments growing in tufts or soft masses, rather rigid, straight and spuriously branched. The branches are younger filaments glued at their bases and part of their length to the parent stem; the apex is delicately hair-like. Heterocysts are normally present and are usually at the base of the branches.

[*C. Braunii* Born. and Flah.; *C. fusca* (Kütz.) Born. and Flah.; *C. parietina* (Näg.) Thur.]

Dichothrix Zanard. Filaments more or less dichotomously branched; several trichomes with their sheaths enclosed within an outer common sheath. Heterocysts basal, or intercalary, or absent in one species.

[*D. gypsophila* (Kütz.) Born. and Flah.; *D. Hosfordii* (Wolle) Born. and Flah.; *D. Orisiniana* (Kütz.) Born. and Flah.]

Isactis Thur. The filaments are erect and parallel, attached at the base. They are glued together by a more or less firm mucilage, and are often encrusted with lime, forming flat strata.

Glœotrichia J. Ag. The filaments, with spores in the lower part, are radiate, sometimes spuriously branched, each enclosed in a distinct, broad sheath, which is often furrowed at the base and transversely folded. All the filaments are enclosed in a more or less spherical jelly.

G. Pisum (Ag.) Thur., Fig. 214.

Rivularia (Roth.) Ag. (**Zonotrichia** J. Ag.; **Limnactis** Kütz.; **Schizosiphon** Kütz., in part).

Filaments radiating, with basal heterocysts, but no spores. A more or less firm mucilage binds the filaments into a hemispherical or bladder-like, well-defined thallus. One species of *Rivularia* has been found in our studies, but no figure of it is given in this report.

FAMILY II. CAMPTOTRICHACEÆ.

Not found in the United States.

SUB-ORDER II. PSILONEMATEÆ.

This sub-order contains the greater part of the Hormogoneæ. The filaments, with or without a sheath, are cylindrical, sometimes showing globular swellings. The sheath may be very thin, hyaline and gelatinous, or tough and lamellose. The apical cell, or sometimes that and the sub-apical cell, are occasionally attenuated, or the filaments may end obtusely.

Key to Families.

1. Filaments showing true branching.......STIGONEMACEÆ
   Filaments showing false branching; heterocysts present ....SCYTONEMACEÆ
   Filaments usually simple, without branching; where they show false branching they are without heterocysts 2
2. Filaments nearly straight; heterocysts absent...... OSCILLATORIACEÆ
   Filaments tortuous; heterocysts present.......... NOSTOCACEÆ

FAMILY I. OSCILLATORIACEÆ.

The distinguishing feature of this family, which is the largest one of the Psilonemateæ, is the absence of heterocysts. The trichomes are a single and regular row of cells, although occasionally false branching is seen. Sometimes the cells are so closely joined that the whole seems a perfectly homogeneous cylinder; but at other times there are constrictions at the ends of the cells. Apical cell sometimes attenuated. The filaments are nearly always in sheaths of various character, which sometimes enclose more than one filament. Some of the genera show gliding or rotary motion. They occur in great profusion, submerged in ponds and ditches, or form scums upon their surface.

There are two sub-families, as follows: —

SUB-FAMILY I. LYNGBYEÆ. Only one trichome in a sheath.

SUB-FAMILY II. VAGINARIEÆ. Several trichomes in one sheath which is often branched.

SUB-FAMILY I. LYNGBYEÆ.

In this sub-family there is never more than one trichome in a sheath, and the sheath may be thick or thin, or even wanting. In some genera the trichomes are twisted. The cells may be of varying thickness and length, but usually the thicker the trichome the shorter the cell. *Oscillatoria, Phormidium,* and *Spirulina* exhibit a rotary or gliding motion.

Key to Genera.

1. Trichomes consisting of many cells................ 2
   Trichomes consisting of one cell, spirally twisted.... *Spirulina**
2. Filaments simple, or falsely branched; sheaths firm; apices of filament straight..................... 3
   Filaments simple; sheaths thin, always hyaline, mucous, and more or less readily fusing together; apices of trichomes straight; oscillating or rotary motion evident.............................. 4
3. Filaments free, or forming felt-like masses; pseudo-branches present, often in pairs.........*Plectonema**
   Filaments forming erect tufts; pseudo-branches often present and solitary ....*Symploca*
   Filaments free and unbranched; free-floating, or forming a matted stratum................*Lyngbya**
4. Filaments more or less agglutinated by their mucous sheaths; cells of filaments often slightly separated by a thin mucous layer................*Phormidium**
   Filaments destitute of sheaths; free, straight or with curved extremities.....................*Oscillatoria**
   Filaments destitute of sheaths; twisted into a regular spiral ....*Arthrospira**

Description of Genera.

Spirulina Turp.— Filaments unicellular, more or less motile, spirally twisted, usually surrounded by a colorless, somewhat liquid mucilage.

S. tenuissima Kütz., Fig. 291.

Plectonema Thur.— Filaments branched, singly or in pairs, quite irregular, each filament enclosed in a separate sheath; cell contents deep blue-green.

[*P. Wollei* Farlow.]

Symploca Kütz.— Filaments simple or showing mere beginnings of branches; in a more or less distinct sheath, rising from a prostrate base; glued together into anastomosing or erect, wick-like clusters.

Lyngbya Ag. (**Leibleinia** Endlicher; **Leptothrix** Kütz., in part; **Spirocoleus** Möbius, in part).— Single filaments enclosed in distinct sheaths, either unbranched or with a suggestion of branching where the filaments break out of the sheaths. Often forming a membranous stratum.

L. sp. (?), Fig. 13.

[*L. ochracea* (Kütz.) Thur.]

Phormidium Kütz. (**Hyphœothrix** Kütz., in part; **Leptothrix** Kütz., in part).— A genus between *Lyngbya* and *Oscillatoria.* Filaments simple, clothed with a thin, hyaline sheath. Sheaths often become fused, and the trichomes are sometimes so numerous as to form mats on damp ground, stones, etc. The cells are sometimes constricted at the ends, and the apical cell may be attenuated or even thickened.

[*P. Corium* (Ag.) Gomont; *P. favosum* (Bory) Gomont; *P. Retzii* (Ag.) Gomont; *P. uncinatum* (Ag.) Gomont.]

Oscillatoria Vaucher (**Oscillaria** Bosc.).— Filaments straight or slightly curved; only in very young specimens are they coiled; simple, without a sheath; mostly bright blue-green, sometimes changing to violet or steel-blue. When in good condition, more or less motile, and involved in a thin mucilage. Found in all sorts of wet places, sometimes even on damp ground and in hot springs.

O. subtilissima Kütz., Fig. 1.

O. æruginco-cœrulea Kütz., Fig. 2.

O. chalybea Mertens, Fig. 14.

O. amphibia Ag., Fig. 15.

O. limosa Ag., Fig. 5.

O. percursa Kütz., Fig. 6.

[*O. princeps* Vauch.; *O. splendida* Grev.; *O. tenuis* Ag.]

Arthrospira Stiz.— Filaments cylindrical, commonly devoid of a sheath, and twisted into a regular spiral. The latter character is the only distinction from *Oscillatoria.*

A. Gomontiana Setchell.— We have not found this species, but Setchell has mentioned it as occurring in Bridgeport.

SUB-FAMILY II. VAGINARIEÆ

Blue-green Algæ, which lack heterocysts, and are distinguished by having one or more trichomes in the same sheath. This sheath is often branched, may be lamellose and colored, or mucous and uncolored.

Description of Genera.

Microcoleus Desm. (**Cthonoblastus** Kütz.).— Trichomes like *Lyngbya,* except that two or more are often enclosed in one sheath, which is at first closed at the end, and later breaks open, sometimes dividing into shreds. The sheath is colorless, not lamellose, large, seldom indistinct.

Schizothrix Kütz. (**Inactis** Kütz.; **Hyphæothrix** Kütz., in part).— Sheaths firm, lamellose, hyaline or colored, and containing few or many trichomes.

[*S. lardacea* (Cesati) Gomont; *S. coriacea* (Kütz.) Gomont.]

FAMILY II. NOSTOCACEÆ.

Cells spherical or oval, arranged in simple chains, or, rarely, with spurious branches. The chain is imbedded in a more or less copious jelly. Some genera are provided with spores and heterocysts. The heterocysts are yellow, straw-colored, or nearly colorless, and are situated at the end of the chain, or between two vegetative cells. Their function is unknown. The dark green, granular spores divide after a period of rest, and then germinate. Many are terrestrial.

Key to Genera.

1. Filaments contorted, within a definite gelatinous tegument .... *Nostoc**

   Filaments more or less straight, free or in a formless slimy mass, not inclosed in a tegument.......... 2

2. Heterocysts terminal, and spores contiguous with them; spores long and cylindrical... *Cylindrospermum**
Heterocysts not terminal 3
3. Filaments aggregated without order......... *Anabæna**
Filaments aggregated in bundles of plate-like masses *Aphanizomenon*

Description of Genera.

Aphanizomenon Morren.— Trichomes a little attenuated towards the apex, glued together parallelly in dense fascicles. Cells nearly cylindrical, light blue or nearly colorless, and slightly granular. Thallus somewhat membranaceous, free-swimming, blue-green, or light pure blue, or at length olive; spores solitary, smooth, cylindrical, elongated, round at the ends, pale blue or olive.

Nostoc Vauch.— Filaments necklace-shaped, enclosed in a more or less distinct gelatinous envelope. The cells are spherical or elliptical, and more or less closely connected, with heterocysts rarely terminal. The filaments are clustered to form thalli, usually surrounded by a membrane, which is sometimes colorless, sometimes dark blue-green, dark brown, light yellow, or, most often, olivaceous.

N. minutissimus Kütz. (?), Fig. 211.
N. sp. (?), Fig. 18.
N. rupestre Kütz., Figs. 16, 17.
N. comminutum Kütz., Fig. 19.
[*N. commune* Vauch.; *N. microscopicum* Carm.; *N. parmelioides* Kütz.; *N. pruniforme* Ag.]

Cylindrospermum Kütz.— Filaments sheathless, single or glued together in an indefinite gelatinous stratum; occasionally a number enclosed in a tegument. Cells spherical, oblong, elliptical, or compressed. Heterocysts single, on the ends of the filaments; spores next the heterocysts very long and cylindrical.

[*C. majus* Kütz.]

Anabæna Bory (**Sphærozyga** Ag.; **Trichormus** Allman; **Dolichospermum** Thwaites).— Filaments similar to those of *Nostoc*, only nearly straight; rarely provided with a sheath;

clustered in gelatinous masses, or single. Cells spherical or nearly so, some of them changing into brownish elongated spores, which are solitary, or one on either side of a heterocyst, or, rarely, in a short series. Heterocysts not terminal.

A. gigantea Wood, Fig. 11.

A. Flos-aquæ Kütz, or *circinalis* (Rab.) Kirch., Fig. 12.

[*A. oscillarioides* Bory.]

Anabæna is very common in reservoirs, and sometimes in combination with *Microcystis* is so abundant as to give the water a very bad taste and smell, and a distinct color. It is one of the most troublesome Algæ in our city reservoirs.

FAMILY III. SCYTONEMACEÆ.

This family is known by its method of branching. Each filament is enclosed in a sheath of uniform thickness, and at intervals penetrates this sheath to form long, flexuose branches which are provided with their own sheaths. The filaments are cylindrical, but thickened toward the growing end, and contain heterocysts. The sheath may be colorless, or yellow, or brown. Reproduction is usually by hormogones, though in some species spores are produced.

Key to Genera.

Branches in pairs, rising between the heterocysts *Scytonema**

Branches single, rising in the region of the heterocysts *Tolypothrix**

Description of Genera.

Scytonema Ag. (**Petalonema** Berkeley; **Schizosiphon** Kütz., in part; **Symphyosiphon** Kütz., in part; **Athrosiphon** Kütz.).— Each filament enclosed in a sheath; branches in pairs produced by a fold of the filament, which breaks through the sheath between the heterocysts. The heterocysts are scattered irregularly throughout the filament. The filaments produce interwoven mats of larger or smaller size. The sheath is lamellose, and yellow or brown in color, generally of an even thickness, but occasionally the margins are irregular.

[*S. crispum* (Ag.) Bornet; *S. Hofmanni* Ag.; *S. myoch-*

thous (Dillw.) Ag.; *S. figuratum* Ag.; *S. ocellatum* (Dillw.) Thur.]

Tolypothrix Kütz. (**Hassallia** Berkeley). — Filaments branched, with a distinct sheath. The branches usually appear where heterocysts occur, the trichome breaking through the sheath just below the heterocyst and continuing its growth. The sheaths are thinner than in *Scytonema.* The heterocysts are sometimes two, three, or four in a row.

[*T. lanata* (Desv.) Wartmann.]

FAMILY IV. STIGONEMACEÆ.

The cells of this family are arranged in a single row or in several irregular rows, in a strong, thick sheath, which is brown and very uneven. The filaments are branched, and grow by repeated division of the cells near the apex. The heterocysts are never terminal, and they are placed in a lateral position when there is more than one filament in a sheath.

Key to Genera.

Normal reproduction by means of hormogones, developed on the extremities of the branches. .*Stigonema**
Normal reproduction by spores. . . . . *Hapalosiphon*

Description of Genera.

Stigonema Ag. (**Sirosiphon** Kütz.).— Cells of the filaments in one, two, or many rows, owing to the lateral division; the older filaments often having as many as ten series, while the younger have only one or two. The cells are surrounded by a membrane which is always distinct, but especially so in the older filaments. The sheath is large, irregular, and usually brown or golden yellow. The generally short, thick branches are irregularly disposed. Found mostly on damp or wet rocks, but sometimes free-floating in lakes or ponds.

[*S. mamillosum* Ag.; *S. minutum* (Ag.) Hass.; *S. panniforme* (Ag.) Born. and Flah.]

Hapalosiphon Näg.— Filaments attached or floating; olive-green, blue-green, or, when older, bright or dark brown. The branches rise singly at right angles to the prostrate stem,

and sometimes bear secondary branches. The cells are granulate, and grow in a single series, rarely in two; they are distinct or, sometimes, continuous. Heterocysts are frequent. The sheaths of the branches, usually colorless, are always thinner than those of the primary filaments. Spores are formed from the ordinary vegetative cells. The plants grow in fresh and salt waters.

CLASS II. BACILLARIEÆ (DIATOMACEÆ).

We have, as yet, given no attention to the *Diatoms*, and they are, therefore, omitted from this report.

CLASS III. HETEROKONTÆ.

The Algæ of this class are unicellular, multicellular, or colonial, appearing as rounded single cells, filaments, or large colonies. The cell walls are usually very thick, and contain many chromatophores of a yellow-green color, without pyrenoids or starch. The ordinary asexual reproduction is by means of zoögonidia, which are pear-shaped bodies furnished with one long and one short cilium. Non-motile spores are also sometimes found with thick walls.

Sexual reproduction takes place by fusion of two similar motile gametes which probably resemble the zoögonidia in having two cilia. Since these gametes are alike they are said to be *isogamous*. This class contains only a single order.

ORDER CONFERVALES.

The various forms are divided into two families, as follows: —

FAMILY I. BOTRYDIACEÆ. Plant body large, globose.

FAMILY II. TRIBONEMACEÆ. Plant body unicellular or filamentous.

FAMILY I. BOTRYDIACEÆ.

Each plant is globose, attached by rhizoids to the damp earth; the chromatophores are numerous and the reproduction varied. This family contains only one genus, which we have not yet found in Connecticut.

Botrydium Wall.— Small, non-cellular, green, globose plants, with colorless, much divided roots, descending into the moist earth, upon the surface of which this Alga lives. The zoögonidia are small, ovoid, and provided with a long cilium. If the plant becomes submerged, the whole may turn into a zoögonidiangium, and the zoögonidia escape through an opening in the apex. Non-motile spores are often produced in great numbers in the rhizoids. If the plant becomes too dry, the green portion migrates into the rhizoids, and a number of spores are produced.

FAMILY II. TRIBONEMACEÆ.

Plants unicellular or filamentous; cells spherical, cylindrical, or elongated, often united to form filaments, and spirally coiled. The cell wall is always firm, and usually thick. Asexual reproduction by zoögonidia. Aplanospores occur in *Tribonema.* Sexual reproduction by isogamous (*i. e.,* similar) gametes.

Key to Genera.

1. Plants unicellular 2
   Plants filamentous, cell wall firm, splitting into H-shaped pieces .... *Tribonema**
2. Cells globose, aggregated in mucilaginous colonies *Chlorobotrys*
   Cells elongate, usually shortly stipitate and often spirally coiled .... *Ophiocytium**

Description of Genera.

Tribonema Derbes and Solier (**Conferva,** as used by Lagerheim). Filaments composed of cylindrical cells, covered with a thick cell wall which frequently breaks up into H-shaped pieces. The cells each contain one or two nuclei and several chromatophores. Asexual reproduction by zoögonidia with two unequal cilia, and by non-motile spores which escape from the broken filaments. Sexual reproduction by isogamous gametes, one of which comes to rest and rounds off before another conjugates with it.

This genus covers many of those forms previously called *Conferva,* a name that is now given up. Hazen places it with

the Ulotrichaceæ, but we follow West in placing it here because of its yellowish-brown color. The plants are abundant in all waters.

T. bombycinum (Ag.) Derbes and Sol., Fig. 48.

T. minus (Wille) Haz., Fig. 21.

Chlorobotrys Bohlin.— Plants are formed of solitary globose cells, or of 2, 4, 8, or 16 cells associated in a family. Each family has surrounding it an ample hyaline mucous tegument. The cell walls are thick and smooth. Six to thirty parietal chromatophores are disposed on the wall of each cell. Sometimes a red pigment spot appears in each cell.

Multiplication by cell division, at first in two directions, afterwards in three.

Ophiocytium Näg. (inclus. **Sciadium** A. Br.). — Cells cylindrical, variously curved, attenuated at one end into a thin, short stem; sometimes both ends rounded, with or without a spine. Propagation by non-motile spores or zoögonidia, which are formed by division of the cell contents. The cell wall has a lid fitted to the apex of a long tube. In the attached species the zoögonidia come to rest on the rim of the empty cell and develop into full-grown cells. A repetition of this process gives a curious branched appearance.

O. parvulum (Perty) A. Br., Fig. 20. The two different sizes are, perhaps, two species. None of our specimens showed the terminal spine.

CLASS IV. CHLOROPHYCEÆ.

This class contains all the green Algæ and numbers more species than all the other classes of Algæ together. The forms are very diverse in size and structure, and include unicellular, filamentous, and colonial plants, some furnished with rhizoids, others with hairs, and some with spines. Cell division usually takes place in all the cells of a thallus, but occasionally there is a growing point. Both sexual and asexual reproduction are found in most of the families of the Chlorophyceæ. This class flourishes most abundantly in fresh water, though many are marine, and members of it are to be found in every damp or wet situation.

The class may conveniently be divided into orders, as indicated by the following key: —

Key to Orders.

1. Thallus cœnocytic (*i. e.*, non-cellular but with many nuclei) ....SIPHONALES
   Thallus filamentous and septate, or unicellular, or expanded 2
2. Thallus filamentous, though filaments may unite in a plane. In the Conjugatæ some are unicellular and not filamentous................................ 3
   Thallus expanded, membranous..............ULVALES
   Thallus neither expanded nor filamentous......... PROTOCOCCALES
3. Cell division by intercalation of new cells producing transverse striation ....ŒDOGONIALES
   Cell division of ordinary type.................... 4
4. Filaments attenuated and commonly ending in a bristle ....CHÆTOPHORALES
   Filaments not ending in a bristle.................. 5
5. Chloroplasts single, substellate, with one pyrenoid. Filaments may fuse in a plane.....SCHIZOGONIALES
   Chloroplasts single, reticulated or band-shaped, without pyrenoids....................MICROSPORALES
   Chloroplasts numerous, parietal, each with a pyrenoid ...........................CLADOPHORALES
   Chloroplasts single or several, large and of some definite shape, with pyrenoids. The entire contents of two cells unite to form a single zygote..CONJUGATÆ

ORDER I. PROTOCOCCALES.

Single-celled green Algæ, without terminal growth or branches, and without vegetative generation of cells; either single or in flocks or families. Sometimes the cells of the families indefinitely increase in number, and form daughter-families. At other times there is a definite number associated together to form colonies called *cœnobia*. Even when apparently closely united, each cell has the power of reproduction, and therefore the plants are essentially unicellular.

The order is a very large one, and contains an immense variety of forms which can hardly admit of a general description. The order is divided into eight families, the following six of which are known in the United States:—

Key to Families.

1. Unicellular, or of a definite number of ciliated motile cells .... VOLVOCACEÆ
   Cells not ciliated or motile 2
2. Cells formed in flat plates or in a network .... HYDRODICTYACEÆ
   Cells not in a plate or a network 3
3. Unicellular and solitary; cell with differentiation of base and apex .... CHARACIACEÆ
   Cells without differentiation of base and apex 4
4. Unicellular and globular, or consisting of short, few-celled filaments (not truly filamentous); firm cell walls; no autospores .... PLEUROCOCCACEÆ
   Cells free or colonial, without copious gelatinous envelope, forming autospores .... PROTOCOCCACEÆ
   Cells spherical and indefinite in number, embedded in a copious gelatinous envelope .... PALMELLACEÆ

FAMILY I. PALMELLACEÆ.

Unicellular Algæ, free-floating or attached, single or in families, with a conspicuous mucous envelope, which is without definite form, and is either structureless or differentiated into concentric envelopes. Cell contents at first homogeneous, later granular, green or reddish. Multiplication by cell division in two or three directions, and cells often grouped in twos or fours. Asexual reproduction by biciliated zoögonidia, several of which arise from an ordinary cell. Sexual reproduction has been observed in some species.

This family is divided into three sub-families, as follows:—

Key to Sub-families.

Cells grouped in twos or fours within a lamellose mucous investment .... GLŒOCYSTIDEÆ
Cells grouped in fours, irregularly disposed in a mucus; cells with a non-motile hair...... TETRASPOREÆ

Cells irregularly grouped within a structureless mucus .... PALMELLEÆ

SUB-FAMILY I. GLŒOCYSTIDEÆ.

Plants formed of colonies of cells in a common mucilaginous envelope. Ordinarily concentric coats of mucus can be seen around single cells or groups of cells. Multiplication by division of the mother-cell into four parts.

Key to Genera.

Colonies irregular .... *Glœocystis**
Colonies cylindrical and branching........ *Palmodictyon*
Colonies subspherical .... *Botrydina*

Description of Genera.

Glœocystis Näg. (**Chlorococcus** Fries., in part).— Spherical or oblong cells associated in globose families of an indefinite number of cells. Teguments gelatinous, formed in layers. Cells spherical or ellipsoidal.

G. vesiculosa Näg., Fig. 28.

[*G. rupestris* (Lyng.) Rab.]

Palmodictyon Kütz.— The cells and surrounding tegument are in the shape of cylindrical masses which branch and anastomose. The outer covering is often hard and of a reddish brown color. Reproduction by means of resting spores with brown cell walls.

Botrydina Breb.— A genus little investigated. The colonies are subspherical, made of cells enveloped in a thick, gelatinous integument, which may be as large in diameter as five hundred microns.

SUB-FAMILY II. TETRASPOREÆ.

Cells grouped in fours or very irregularly scattered towards the outside of a structureless mass of jelly. The cells of this family are frequently provided with delicate non-vibratile hairs called *pseudocilia.*

Description of Genera.

Tetraspora Ag.— Thallus gelatinous, thick, at first baggy, then lengthening; scattered through the jelly are numberless

green cells, dividing in one or more directions, grouped in twos or fours without order near the periphery. Isogamous *planogametes* — *i. e.*, provided with cilia,— biciliated zoögonidia, and resting spores with thick brown cell walls, are developed.

T. lubrica (Roth) Ag. var. *lacunosa* Chand., Fig. 212.

T. gelatinosa (Vauch.) Desv., Fig. 77.

[*T. bullosa* (Roth) Ag.]

Apiocystis Näg.— Thallus small, of various or changing color, fastened by a stem-like base. Cells spherical, sometimes scattered, sometimes eight in a circle; contents homogeneous or slightly granular, with a distinct colorless vacuole. Propagation by globose zoögonidia, each bearing two cilia, and isogamous gametes.

SUB-FAMILY III. PALMELLEÆ.

A large number of globose cells are aggregated in a structureless mass of jelly, which is of indefinite extent except in *Palmodactylon,* in which it is more or less cylindrical and variously branched. The outer layers of the firm, thin cell walls are thrown off from time to time in one or many pieces.

Description of Genera.

Palmella Lyng. — A shapeless mass of jelly, holding cells which are spherical, oval, or oblong, green, red, or brown. Multiplication by repeated division of the cell contents, accompanied by decided gelatinization of the wall of the mother-cell. Reproduction by micro- and macro-zoögonidia and also by small isogamous planogametes.

P. mucosa Kütz. (?), Fig. 72. Fig. 72*a* is the gelatinous colony, natural size.

Schizochlamys A. Br.— Found with *Tetraspora,* and like it, except that in this genus the cell wall often splits into four parts. The cell contents afterward divide into two or four daughter-cells.

Palmodactylon Näg.— Small round cells, dull green, enclosed in a cylindrical bladder-like membrane. Several of these membranes are often joined together at one end, spread-

ing radially. One, two, or four series of cells in each membrane.

FAMILY II. PROTOCOCCACEÆ.

The vegetative cells are green, strictly unicellular, and are not provided with cilia. Propagation either sexual or asexual. In the latter case the cells divide into many parts, the whole assuming the form of a new colony. These are called *autospores* and *autocolonies*. Division of vegetative cells lacking. In some genera the cells are united into definite regular forms called *cœnobia,* in others into a *pseudocœnobium,* which differs from the true *cœnobium* in that the cells are not all of the same generation; other genera have the cells scattered or congregated into irregular forms.

Key to Sub-families.

1. Cells elongated, frequently curved; solitary or in definite, loosely coherent colonies....... SELENASTREÆ
   Cells angular, with a definite number of angles, two, four, six, eight, or more; cells solitary... TETRAEDREÆ
   Cells variable, united in a regular flat plate.. CRUCIGENIEÆ
   Cells globose or sub-globose.................... 2
2. Cells strictly globose, united in a spherical colony (cœnobium) .... CŒLASTREÆ
   Cells globose or sub-globose, not united in a spherical cœnobium 3
3. Cells with two or more attenuated bristles... PHYTHELIEÆ
   Cells without bristles........................... 4
4. Cells generally retained within enlarged wall of mother-cell .... OÖCYSTIDEÆ
   Cells joined in colonies by persistent walls of mother-cells, which sometimes become transformed into connecting threads................ DICTYOSPHÆRIEÆ

SUB-FAMILY I. DICTYOSPHÆRIEÆ.

Cells globose, ovoid, or ellipsoid, and associated to form indefinite colonies. The cells are held in position, usually, by the wall of the mother-cell, which in some genera breaks up into connecting threads. Multiplication by simple vegetative

division, or by the formation of four daughter-cells in a mother-cell, which at length ruptures to let them out.

Key to Genera.

1. Cells indefinitely disposed........................ 2
   Cells in grape-like clusters, freely exposed in a thin gelatinous envelope..............*Botryococcus*
2. With well-marked, subdichotomous connecting threads; chloroplast parietal.........*Dictyosphærium**
   Cells in radiating series; connecting threads scarcely visible; chloroplast axile................*Dictyocystis*

Description of Genera.

Botryococcus Kütz.— Sixteen or thirty-two cells clustered like a bunch of grapes in an irregularly lobed mucous thallus. Cells oval, spherical, or elliptical, densely packed in families within a thin tegument. Clusters free-swimming, green, at length pallid or brown.

Dictyosphærium Näg.— Cells green, kidney-shaped or egg-shaped, gathered into a hollow, somewhat spherical family, and usually surrounded by a gelatinous envelope; free-swimming. Cells covered by thick coats which are confluent; joined by a fine tegument. Division of cells at first in all directions, later only radially. Biciliated zoögonidia rarely occur.

D. Ehrenbergianum Näg., Fig. 22.

Dictyocystis Lagerh. — Oblong or cylindrical cells, held in radiating series by delicate threads, to form a small, free-floating colony, the series often branching.

SUB-FAMILY II. TETRAEDREÆ.

Solitary unicellular plants, flattened and angular with a definite number of angles. The angles may be rounded, notched, or furnished with spines. Only one genus, sometimes divided into two, according to the depth of the lobulation.

Tetraedron Kütz. (**Polyedrium** Näg.).— Cells green, single, free-swimming, three-, four-, or eight-angled; angles rounded, sometimes notched, mostly armed with a spine.

Propagation by means of autospores, which are formed, usually to the number of four or eight, in the mother-cell.

T. minimum (A. Br.) Hansg., Fig. 23.
T. trigonum var. *punctatum* (Kirch.), Fig. 24.
T. trigonum var. *pentagonum* (Rab.), Fig. 25.

SUB-FAMILY III. OÖCYSTIDEÆ.

Cells spherical or elliptical, often retained within the swollen wall of the mother-cell. There may be one or several parietal chloroplasts. The cell wall of all but *Palmellococcus* is firm. Multiplication by means of autospores, which often develop and grow to full size in the mother-cell.

Key to Genera.

1. Cells curved, subcylindrical or sublunate. . *Nephrocytium**
   Cells ellipsoidal . . . . *Oöcystis*
   Cells spherical 2
2. Cells large, solitary and free-floating. . . . *Eremosphæra*
   Cells minute, forming a thin stratum. . . . *Palmellococcus**

Description of Genera.

Nephrocytium Näg.— Two, four, eight, or sixteen oblong or kidney-shaped cells, associated in a free-swimming family, surrounded by an oval or kidney-shaped covering. Of variable size; cells bright green. Frequent in ponds. Multiplication by autospores, which are often spirally disposed around the inside of the wall of the mother-cell.

N. Nægelii A. Br., Figs. 26, 29.
N. Agardhianum Näg., Fig. 27.

Oöcystis. This genus differs from *Nephrocytium* in having cells ellipsoidal and showing polar nodules. There are usually several parietal chloroplasts in each cell.

Eremosphæra D. By. (**Chlorosphæra** Henfrey).— Large, spherical, free-swimming cells, with firm walls, showing a colorless border. Cell contents green, granulose; each cell containing large numbers of small parietal chloroplasts. Multiplication into two or four parts, which escape through the cell wall. Found in small pools.

Palmellococcus Chodat (**Protococcus** Ag., in part).— Strictly unicellular Algæ, globose, green, sometimes changing to red upon exposure. Cells formed singly or in clusters, growing in water, or on damp soil, flower-pots, trunks of trees, etc.; 8, 16, 32, or 64 spores formed within a mother-cell, the wall of which ruptures and sets them free. Very rapid multiplication by cell division.

P. sp. (?), Fig. 30.

P. Gigas (Kütz.), Fig. 31.

SUB-FAMILY IV. SELENASTREÆ.

Cells elongated and attenuated, sometimes lunate; solitary, or joined into fragile families. A single chloroplast, which may contain one or many pyrenoids, is found in each cell. The cell wall is delicate but firm. Multiplication by autospores or autocolonies.

Key to Genera.

1. Colonies enveloped in mucus............*Kirchneriella**
   Colonies almost destitute of mucus................ 2
2. Cells attenuated to acute apices.................... 3
   Cells sublunate or ellipsoidal, arranged in groups of four in a plane; groups forming irregular colonies *Dimorphococcus*
3. Cells forming definite colonies of a row of cells in one plane ....*Scenodesmus**
   Cells solitary or loosely grouped in irregular bundles *Ankistrodesmus**
   Cells lunate, arranged back to back.......*Selenastrum**
   Cells dividing, oblique; daughter-cells remaining attached loosely by their apices...........*Dactylococcus*

Description of Genera.

Kirchneriella.— The cells are bent like a bow, often until their apices almost touch each other; loosely aggregated within an enveloping mass of jelly. The cell wall is thin, the chloroplast parietal; multiplication by autospores, four or eight of which are produced in a mother-cell. The genus differs from *Selenastrum* in the presence of jelly.

K. obesa (West) Schmidle, Fig. 54.

Selenastrum Reinsch.— Cells lunate, attenuated on both ends to a fine point, with firm, thin walls; arranged back to back to form four- to eight-celled colonies. Multiplication by autospores.

S. acuminatum Lagerh., Fig. 46.

S. sp. (?) (perhaps *acuminatum*), Fig. 43.

Scenodesmus Meyen.— Cells elliptical, cylindrical, oblong-spherical, often drawn out into longer or shorter spines. One, sometimes two, rows of cells are commonly joined laterally into a cœnobium. Propagation by repeated division of the cell contents into brood-families, which are set free by rupture of the mother-cell wall.

S. obtusus Meyen, Fig. 38.

S. caudatus Corda, Fig. 36.

S. caudatus var. *abundans* Kirch., Fig. 32.

S. caudatus var. *typicus* Kirch., Fig. 33.

S. caudatus var. *setosus* Kirch., Fig. 34.

S. acutus Meyen, Fig. 37.

S. dimorphus Kütz., Figs. 42, 44.

S. antennatus Breb. var. *rectus* Wolle, Fig. 39.

S. sp. (?), Fig. 35.

Dimorphococcus A. Br.— Cells united more or less in fours on short branches; the two intermediate, contiguous cells oblique, obtuse-ovate; the two lateral, opposite and separate from each other, lunate; families free-swimming, in irregular clusters.

Ankistrodesmus Corda (**Rhaphidium** Kütz.; **Schröderia** Lemmermann).— Finely granulate, cylindrical cells, usually tapering at both ends and variously curved. The cells occur singly, or gathered into groups, several radially joined, two crossing each other, rarely two united at the end; covering thin and smooth; division in only one direction.

A. falcatus (Corda) Ralfs, Fig. 45.

A falcatus var. *acicularis* West, Fig. 47.

A. falcatus var. *mirabilis* West, Fig. 41.

A. Braunii (Näg.) (?), Fig. 40.

SUB-FAMILY V. CRUCIGENIEÆ.

Cells gathered into flat cœnobia. The cells are generally rounded and sometimes furnished with spines. The groups of

four are held together by a tough mucilage. Multiplication by autocolonies. The only American genus is the following:—

Crucigenia Morren (**Staurogenia** Kütz.; **Lemmermannia** Chodat; **Willea** Schmidle).— 4, 8, 16, or 32 subquadratic cells, gathered into a flat cœnobium held in a mucilaginous envelope. As many as 128 cells in groups of four have been discovered. The cell walls are smooth, and each cell is furnished with a single chloroplast. Multiplication by autocolonies.

SUB-FAMILY VI. PHYTHELIEÆ.

Unicellular or grouped in a more or less definite cœnobium, freely floating. Almost devoid of a mucous envelope and furnished with bristles.

SUB-FAMILY VII. CŒLASTREÆ.

The cells are either globose or polygonal, provided with processes by which they are united into a hollow sphere; or broadly lunate, and united at the centre by short stalks. Propagation by autocolonies which are formed in each cell of the cœnobium.

Key to Genera.

Cœnobium hollow .... *Cœlastrum**
Cœnobium solid.......................... *Sorastrum**

Description of Genera.

Cœlastrum Näg. (**Hariotina** Dang.). — Cœnobium a hollow globe formed of a single layer of green, spherical or angular cells; later the cœnobium appears to be reticulately pierced; in older growths the cells have become polygonal through continued pressure. Daughter-cœnobia are developed within the mother-cell, and escape by breaking the walls of the latter. Found in ponds.

C. microporum Näg., Fig. 51.

Sorastrum Kütz. (**Selenosphærium** Cohn).— Differs from *Cœlastrum* in that the cœnobium is solid. It is composed of 4, 8, 16, or 32 wedge-shaped stalked cells, radially disposed, with spines (usually two) on each end. Propagation by autocolonies.

S. spinulosum Näg. (?).— The common form of *Sorastrum* in this region is shown in Fig. 213. It shows only one spine at each corner. A less common form which may be a different species is shown in Fig. 55.

FAMILY III. HYDRODICTYACEÆ.

These plants are free-floating, non-motile cœnobia, composed of cells arranged like a net or in a flat plate. *Pediastrum* may have fifty cells and *Hydrodictyon* many hundreds. Multiplication by autocolonies. Reproduction by spores, which become quiescent within the mother colony and then unite by their extremities to form a new cœnobium. A fusion of isogamous gametes to form a zygospore also sometimes occurs. The two sub-families are probably not closely related.

Key to Sub-families.

Cells in a flat plate........................PEDIASTREÆ
Cells form a network..................HYDRODICTYEÆ

SUB-FAMILY I. PEDIASTREÆ.

Microscopic plants composed of a number of small cells united into a flat disk. Zoögonidia formed in the mother-cell are liberated into an external vesicle, and there form new cœnobia.

Description of Genus.

Pediastrum Meyen.— The plane, discoid or stellate, free-swimming cœnobium is formed of a single, rarely a double, layer of green cells, perforated or continuous. The cells are polygonal, with four or more sides; the central cells are entire, while the marginal cells are often bilobed; the lobes are wedge-shaped, simple or bidentate, sometimes drawn out into hair-like ends. The genus is very abundant and variable. The reproduction is as follows:— The cell contents are at first homogeneous, later becoming granular. The granular contents divide into small zoögonidia, spherical or nearly so, which break away from the mother-cell into an external vesicle. After they have been motile awhile, they come to rest, and then divide and redivide; a gelatinous covering forms around them, the cells arrange themselves into a single layer, and gradually take on the shape of the mother plant. Autocolonies

are sometimes found in a single cell. Biciliated gametes are also found which conjugate.

P. sp. (?), Fig. 65.

P. pertusum Kütz., Figs. 66, 68, 70, 71.

P. pertusum var. *clathratum* A. Br., Figs. 50, 52, 57.

P. tetras Ehrb., Fig. 69.

P. Boryanum (Turp.) Menegh. var. *granulatum* Kütz., Figs. 58, 59, 67.

P. Ehrenbergii A. Br., Figs. 61, 62, 63, 64.

SUB-FAMILY II. HYDRODICTYEÆ.

Plants large, composed of a number of large cells, which are so arranged as to form a net. Zoögonidia swarm and become quiescent within the mother-cell, and there unite to form new cœnobia.

Hydrodictyon Roth.— Cœnobium large, composed of oblong cells joined at the ends, forming a reticulated stratum, at first baggy, then net-like. All the cells are fertile, breaking up to form large numbers of microgonidia within the mother-cœnobium. After a period of activity they come to rest and form a new cœnobium by joining together at their extremities. Sometimes they become perfectly dry; but, when moistened, they form biciliated macrogonidia which join themselves into daughter-cœnobia within the mother-cell. Motile gametes are also found which become free and conjugate into a globose zygote. The only known species is the following:—

H. reticulatum (L.) Lag., Figs. 215, *a, b, c.*

FAMILY IV. PLEUROCOCCACEÆ.

Plants mostly unicellular, sometimes composed of short, creeping, slightly branched filaments, which are never attenuated to hairs. The cell walls are generally very firm, and the cells aggregate to form indefinite colonies. Multiplication by division in two or three directions. Asexual reproduction sometimes by means of biciliated zoögonidia. Of the six genera of this family we have found only one.

Pleurococcus Menegh. (**Protococcus** Ag., in part; **Cystococcus** Näg.; **Chlorococcus** Fries, in part; **Pseudo-pleurococcus** Snow).— The cells are usually globular, sometimes angular from pressure. Division occurs in three direc-

tions, so at times a cubical colony is seen, which easily divides into its respective cells. The plants are occasionally creeping, branched filaments. A single parietal chloroplast is present, with or without a pyrenoid. Reproduction by aplanospores — *i. e.*, without cilia,— by rejuvenescence of the mother-cell contents, by isogamous gametes, or by biciliated zoögonidia.

P. vulgaris Menegh., Fig. 73, is a very common form in the state, growing in damp places, upon stones, etc. We have not found it in water.

FAMILY V. CHARACIACEÆ.

Plants unicellular, usually elongated and attenuated at both ends, the lower end terminating in a stalk, generally furnished with a disk by which it is attached to larger Algæ. A single parietal chloroplast with one pyrenoid is present. Reproduction by numerous zoögonidia formed by division of the cell contents at first transversely, then longitudinally. These portions become rounded off, become biciliated, and escape by a lateral, or, more rarely, a terminal pore. Each zoögonidium becomes a new plant on coming to rest.

Characium A. Br.— Coextensive with the family.

C. Nægelii A. Br., Fig. 53.

C. ambiguum Herm., Fig. 56.

FAMILY VI. VOLVOCACEÆ.

Plants unicellular, or consisting of cœnobia with a definite number of cells, always ciliated and motile. Multiplication by division of the mother-cell into 2, 4, or 8 daughter-cells. Reproduction both by the union of isogamous planogametes and, in the higher genera, by heterogamous gametes.

The Volvocaceæ are sometimes found in immense quantities, and frequently give an oily taste and odor to drinking water. They are closely related to the *Flagellata*, and some of them are frequently classed with the *Protozoa*.

Key to Sub-families.

Composed of colonies of many cells; cells with two cilia .... VOLVOCEÆ

Composed of single cells with two, or rarely four, cilia .... CHLAMYDOMONADEÆ

SUB-FAMILY I. VOLVOCEÆ.

Motile cœnobia; cells varying in number from 4 to 20,000, globose or ovoidal, with a distinct but thin cell wall; cilia two; chloroplast one of very variable form, usually including a single pyrenoid. Cells usually imbedded in a common mucilaginous investment; more rarely united by protoplasmic processes. All the cells may be capable of reproducing the plant, or there may be a differentiation into vegetative and reproductive cells. Vegetative reproduction by division of some or all of the cells to form daughter-cœnobia. Isogamous or heterogamous sexual reproduction.

Key to Genera.

1. Colonies spherical or circular 2
   Colonies flat, cells 4-16, angles rounded, in a colorless sheath.............................. *Gonium*
2. No gelatinous covering, cells many, in a hollow globe *Volvox**
   No gelatinous covering, cells 16, arranged in four rows ....*Spondylomorum**
   With a gelatinous covering...................... 3
3. Colony ovate or spherical........................ 4
   Colony of eight cells, in an equatorial zone in a spherical or ellipsoidal investment.....*Stephanosphæra*
4. Cells 16-32, globose, not crowded, but scattered at regular intervals on a colorless sphere......*Eudorina**
   Cells 8, 16, 32, or 64, globose, crowded, often angular from pressure.........................*Pandorina**

Description of Genera.

Gonium Müller (inclus. **Tetragonium** West).— Four to sixteen cells so placed in a flat stratum as to form a quadrangle with rounded angles. A colorless tegument covers all. Cells globular except when angular from pressure. The cilia all arise from one surface of the colony. When old, the cells become granular and are connected by produced angles. Reproduction by repeated division of the cytoplasm into zoögonidia. Multiplication by daughter-cœnobia formed in each cell of the mother-cœnobium.

Volvox Ehrb.— Cœnobium spherical, hollow, the surface composed of green cells estimated as high as 22,000, arranged regularly on the wall, and each provided with two cilia, which reach through the gelatinous covering and keep the cœnobium in constant motion. Each green cell is attached to the six surrounding ones by fine threads which are difficult to see even under high power and with favorable light. *Oögonia* and *antheridia* are developed from vegetative cells, and a brown, smooth or star-shaped cell is often found which is supposed to be a fertilized oöspore in a resting stage. Asexual reproduction takes place by the division of the larger vegetative cells, which form new families. These after sufficient growth separate from the mother-cell and begin life independently.

V. aureus Ehrb., Fig. 75.

V. globator (L.) Ehrb., Fig. 76. Fig. 74 is a fertilized oöspore. These are frequently found within the cœnobia, and also occur free in the water. Ehrenberg named it *V. stellata,* but of course this was an error.

Spondylomorum Ehrb. (**Uvella** Ehrb.; **Phacolomonas** Stein.).— Cœnobium of sixteen cells in four alternating rows, each cell with four cilia.

S. quaternarium Ehrb., Fig. 288.

Stephanosphæra Cohn.— Eight green cells, each having two vibrating cilia, are arranged at regular intervals in an equatorial circle, enclosed in a colorless sphere. Propagation by macrogonidia, formed by eight-fold division of the green cells, each bearing two cilia and a lateral red spot, and gathered into families of eight; or by microgonidia, each provided with four cilia, formed by repeated division, and at first revolving within the common sphere, afterwards escaping singly. In hollow rocks and pools after rain.

Eudorina Ehrb. (**Eudorinella** Lemmermann).— Cœnobium somewhat oval or spherical, composed of 16 or 32 globular green cells, each with two cilia, arranged around the colorless sphere at nearly regular intervals. Usually four of the 32 cells develop antheridia and the rest oögonia for the sexual reproduction. Asexual reproduction by the division of the cells into 16 or 32 parts to form daughter-cœnobia.

E. elegans Ehrb., Fig. 285.

Pandorina Bory.— Cœnobium spherical, covered by a colorless jelly. Cells 8, 16, or 32, green, spherical, each covered with a thin membrane and furnished with two widely divergent cilia, often so crowded as to be angular. Propagation sexual, by the conjugation of isogamous gametes. Cells of a cœnobium divide into eight daughter-cells; these become two-ciliated gametes, and are scattered and conjugate with similar cells from other cœnobia; they flow together and produce a zygospore, which, after a season of rest, develops one to three biciliate macrospores, and these in their turn develop new cœnobia. Asexual multiplication by formation of a daughter-cœnobium from each of the cells of the mother-cœnobium.

P. morum (Müll.) Bory, Figs. 286, 287.

SUB-FAMILY II. CHLAMYDOMONADEÆ.

The plants are unicellular, spherical or ovoid, with thin walls, and two or rarely four cilia. The chloroplast is in the posterior end of the cell and usually contains one pyrenoid. Reproduction by division of the resting cell into 2, 4, or 8 daughter-cells. Non-motile spores sometimes occur. Sexual reproduction by conjugation of ciliated gametes, either isogamous or heterogamous, which are similar to the vegetative cells, though smaller. They arise by division of the contents of the mother-cell, sometimes as many as 64 resulting from one cell.

Key to Genera.

Contents of cell close to cell wall...... *Chlamydomonas**
Contents of cell connected with cell wall by threads *Sphærella*

Description of Genera.

Chlamydomonas Ehrb.— Vegetative cells ovate, green, enclosed in a narrow, colorless tegument, frontal extreme sometimes produced to a beak with two cilia, other end with large chloroplast, and with or without a red lateral spot. Gametes formed by continued division of cell contents of vegetative cells, numerous, oblong, or ovate, pale green or yellow, afterwards brownish. Zygospores globular, red or brownish.

Chlamydomonas is abundant in the reservoirs of the state.

C. pulvisculus Ehrb., Fig. 289.

According to West the forms with four cilia should be named *Carteria*, Fig. 290. Both the two- and the four-ciliate forms are common in our waters.

Sphærella Sommerfeldt (**Chlamydococcus** A. Br.; **Hæmatococcus** Ag.).— Like *Chlamydomonas*, except that the cell walls are outstanding and joined to the cell contents by fine threads. There is always more or less red coloring matter present.

[*S. lacustris* (Girod.) Witter.]

ORDER II. ULVALES.

Thallus expanded and parenchymatous; attached when young by rhizoids. Each cell is furnished with a single nucleus and a parietal chloroplast, often quite large, containing one pyrenoid.

FAMILY I. ULVACEÆ.

Most of the genera of this family are inhabitants of salt or brackish water. The thallus consists of an expanse of cells arranged compactly with their longer axes at right angles to the plane of the thallus; either flat or, more rarely, tubular. The cells are uninucleate, with a single parietal, often ragged, chloroplast, containing one pyrenoid.

Asexual reproduction by zoögonidia with 4 cilia, and by gemmæ. Sexual reproduction by isogamous gametes. The contents of a vegetative cell divide into 8 (sometimes 4 or 16) gametes, smaller than the zoögonidia, which are pear-shaped, with a pigment spot and two long cilia. As a result of conjugation a rounded cell with two pigment spots and 4 cilia is formed, which becomes a zygospore on losing its cilia.

Enteromorpha Lk.— Thallus tubular, membranaceous; at first fixed, then floating; sometimes branched. It is either green or pale olive-colored. Reproduction as in the family. Found in salt or fresh water.

ORDER III. SCHIZOGONIALES.

The thallus, often attached by rhizoids, is filamentous, sometimes several filaments being joined laterally to form a flat

plate. Each cell contains one nucleus and a central stellate chloroplast with one pyrenoid. The cells, especially of young plants, often divide in two or three directions.

FAMILY I. PRASIOLACEÆ.

Coextensive with the order.

Prasiola Ag. (inclus. **Schizogonium** Kütz., and **Hormidium** Kütz., in part).— Found on moist earth, trunks of trees, rocks, stones, etc.; some species require very little moisture. The cells of the filamentous thallus are broader than long, and those of the flat plates quadrate or polygonal. The cell walls are strong and colorless. Reproduction by gemmæ, by resting spores liberated at the margin of the thallus, and by tetraspores.

ORDER IV. CHÆTOPHORALES.

Thallus filamentous, simple or usually branched. Branches generally attenuated and bearing long hairs. The uninucleate cells possess each, except in *Trentepohliaceæ,* a single parietal chloroplast with one or more pyrenoids. Asexual reproduction by resting spores or zoögonidia with two cilia. Sexual reproduction by isogamous planogametes with two cilia, or by heterogamous gametes.

Key to Families.

1. Plant entirely filamentous, simple................. 2
   Plant of branched filaments forming a flat cushion-like expansion enveloped in mucilage............ COLEOCHÆTACEÆ
2. Filaments branched............................ 3
   Filaments not branched......................... 5
3. Gametes arise from special cells only............ TRENTEPOHLIACEÆ
   Gametes arise from any cell of the filament........ 4
4. Small creeping filaments upon water plants; cells globose or cylindrical ..............HERPOSTEIRACEÆ
   Like the above, but with flask-shaped cells....... CHÆTOSPHÆRIDIACEÆ
   Plant not creeping...................CHÆTOPHORACEÆ

5. Cells with thick lamellose coats, in a series inside a lamellose sheath .................CYLINDROCAPSACEÆ
Cells without lamellose coat.............ULOTRICHACEÆ

FAMILY I. TRENTEPOHLIACEÆ.

Thallus filamentous and branched, filaments erect or creeping, growing on the ground or on tree trunks. The cell walls are firm and lamellose. The cells are uninucleate, and possess one or many parietal chloroplasts with or without pyrenoids. The color of the plants is usually brown or reddish. Zoögonidia are developed only in cells especially set apart, either on the ends of the branches or intercalated. These motile spores sometimes conjugate. Spores are sometimes produced which rest for a period before germinating, called *resting spores* or *hypnospores.*

Key to Genera.

Terrestrial or arboreal; chloroplasts several...... *Trentepohlia**
Aquatic; cells that produce zoögonidia are terminal *Gongrosira*
Aquatic; cells that produce zoögonidia not terminal *Leptosira*

Description of Genera.

Trentepohlia Mart. (**Chroölepus** Ag.).— Filaments irregularly branched, often so dense that the branches and stem cannot be easily distinguished; primary branches and stem of same thickness. Cell contents reddish brown, golden-yellow, or olive-colored. About 32 red-brown or golden-yellow zoöspores in a cell which is set apart especially for the purpose, usually on the end, sometimes on the side of the filament.

[*T. aurea* (L.) Mart.; *T. Iolithus* (L.) Wittr.]

Gongrosira Kütz. (inclus. **Pilinia** Kütz., in part).— The plant is attached by a mass of cells, formed by a confluence of creeping branches. From this mass, which may be of one or many layers of cells, numerous erect branched filaments arise. The whole is frequently encrusted with lime. The cell walls are thick and lamellose, and the chloroplast is parietal with one or many pyrenoids. Zoögonidia are found in flask-

shaped, terminal zoögonidiangia. The spores are ordinary cells from the recumbent branches which become detached.

Leptosira Borzi.—Very much like *Gongrosira.* The thallus is in the form of a minute bright green cushion. The cells are light yellow-green, the terminal cells being elliptical or irregular. The zoögonidiangia are intercalated and not terminal. The zoögonidia either germinate directly, or conjugate in pairs and form resting spores. The ends without cilia fuse first in conjugation.

FAMILY II. CHÆTOPHORACEÆ.

The thallus is branched, and the branches are attenuated sometimes into long hyaline hairs; it is usually differentiated into creeping and erect portions. The creeping portion is attached by rhizoids, is branched, and is more or less torulose. The cells of the creeping portion are more or less swollen, and the branching is irregular. Each cell, except those of the terminal hairs, is provided with a parietal irregular chloroplast, containing a single pyrenoid.

Zoögonidia, from 1 to 16, may be produced in each cell of the thallus except those of the rhizoids and the terminal hairs. They possess a red pigment spot and 2 or 4 cilia, and vary much in size. Spores of a red-brown color are produced in all the genera of the Chætophoraceæ. The gametes possess only two cilia, conjugate in pairs, and produce zygospores which rest for a short period before germinating.

Key to Genera.

1. Plants less than 1 mm. high, without setæ...... *Microthamnion**
   Plants larger, branches attenuated, and with setæ... 2
2. Filaments fine, showing little difference in character of stem and branch, not in tufts in gelatinous masses ....*Myxonema**
   Filaments fine, in tufts in a dense gelatinous substance *Chætophora**
   Filaments and main branches large, bearing tufts of small branchlets.......................*Draparnaldia**

Description of Genera.

Microthamnion Näg.— Filaments articulate, variously branched, straight; end cell at first linear, then obtuse, and finally swollen into a sporangium. The plants are at first fixed, but later free-floating. The branches arise just below a transverse cell wall. The chloroplast is parietal, long and entire, and lacks a pyrenoid.

This genus is frequently placed with the *Trentepohliaceæ*; but Hazen states that the zoögonidia may be produced in any cell of the filament, and hence it has its relationship near *Myxonema*. Two species are found in Connecticut, according to Hazen.

[*M. Kuetzingianum* Näg.; *M. strictissimum* Rab.]

Myxonema Fries (**Stigeoclonium** Kütz.).— Filamentous, simple, branched, articulate; the branches not in tufts, in appearance much like the main stem, with the end cells often drawn out into long, colorless bristles. The chloroplasts are scattered or arranged as in *Draparnaldia*. One to many zoögonidia, each with two or four vibrating cilia, formed from the contents of one cell. Gametes with 4 cilia. Zygospores smooth or stellate.

M. attenuatum Haz., Fig. 220.

M. tenue (Ag.) Rab., Figs. 79, 82.

M. nanum (Dillw.) Haz., Fig. 284.

M. lubricum var. *varians* Haz., Fig. 81.

M. sp. (?), Fig. 78.

[*M. flagelliferum* (Kütz.) Rab.]

Chætophora Schrank.— Plants enveloped in a hard, gelatinous covering of a globose, plane or lobed form. Thallus filamentous, articulated and branched. Stems radiately disposed, dividing into short branchlets, sometimes ending in a bristle. The zoögonidia have two or four cilia, and resting spores are generally developed from terminal cells and are brown.

C. incrassata (Huds.) Haz., Fig. 221.

C. pisiformis (Roth) Ag., Fig. 222.

[*C. attenuata* Haz.]

Draparnaldia Ag.— Filaments articulate, much branched. The stem is thick and composed of sterile cells, colorless

except for the chloroplast, which is in the shape of a transverse band. The filaments are furnished more or less densely with alternate or opposite, tufted branches. These are composed of smaller, green, fertile cells, the end cell often a colorless spine. From one to four zoögonidia, with four cilia apiece, arise from each cell of the lateral branches. Usually all the cells of one tuft form zoögonidia at the same time, and the whole process occupies but a few minutes. A gelatinous sheath, soft and slippery, covers the whole. Found in clear streams, attached to stones or water-plants.

D. plumosa (Vauch.) Ag., Figs. 83, 84.
D. glomerata (Vauch.) Ag., Fig. 217.
[*D. acuta* (Ag.) Kütz.]

FAMILY III. CYLINDROCAPSACEÆ.

Filamentous green Algæ, without branches or roots, living either in water or air. The filaments are covered with a thick, lamellose sheath, and the cells are lamellose and are in a single series.

In an ordinary vegetative cell the contents mass together to form one oösphere. The antherozoids, which change from green to red or orange, are each provided with two short cilia. After the oösphere is fertilized, it also changes to red or orange, and lies resting for some time before it germinates.

Cylindrocapsa Reinsch.— With the characters of the family. They are at first attached, then floating.

FAMILY IV. ULOTRICHACEÆ.

Filaments simple, composed of cylindrical or of rounded cells. The cell wall is always colorless, though of varying thickness. Each cell contains a single parietal chloroplast with irregular margins and one pyrenoid. Asexual reproduction takes place in various ways. Both motile and non-motile spores are produced; of the former some are large (macrozoögonidia) and some small (microzoögonidia). The plants also multiply by dismemberment of the filament into single cells or series of cells. Sexual reproduction by isogamous gametes.

Key to Genera.

Filaments attached; chromatophore a homogeneous zonate band, with one to several pyrenoids... *Ulothrix**

Filaments not attached; chromatophore a parietal disk or plate, with one pyrenoid........ *Stichococcus**

Filaments generally not attached; chromatophore granular, covering more or less completely the whole cell wall, containing starch but no pyrenoids *Microspora**

Description of Genera.

Ulothrix Kütz. (**Hormiscia,** as used by Rabenhorst, Hansgirg, and De Toni).— Filaments simple; each cell except the basal cell capable of reproduction. The chloroplast is parietal with one or many pyrenoids. Asexual reproduction by zoöspores. Sexual reproduction by conjugation of gametes, of which eight or more may be formed in a cell.

U. zonata (Web. and Mohr) Kütz., Fig. 94.

U. tenerrima Kütz., Fig. 93.

Figures 86 to 91 are specimens of *Ulothrix* of which we have not determined the species.

[*U. implexa* Kütz.; *U. flacca* (Dillw.) Thur.]

Stichococcus Näg. (**Hormococcus** Chodat).— Very like *Ulothrix,* but unlike it in being almost wholly aerial, and in the fact that the filaments easily and commonly dissociate into cylindrical cells or small groups. The dissociation frequently occurs first on the one side and then on the other, giving a zig-zag appearance. Each cell has a parietal chloroplast, usually occupying a part of the cell wall and containing a small pyrenoid. Propagation by cell division, breaking up of the filaments, by non-motile spores, and by biciliated zoögonidia.

S. flaccidus (Kütz.) Gay, found but not figured.

[*S. rivularis* (Kütz.) Haz.]

Microspora Thur.— Filaments composed of cylindrical or slightly swollen cells. The firm, sometimes lamellose cell walls occasionally break up into H-shaped pieces, each piece composed of a transverse wall and portions of the lateral walls of the two adjoining cells. The cells are uninucleate, and a more or less reticulated chloroplast occupies the cell wall.

Resting spores with thick walls are produced, usually one in each cell, and also two- to four-ciliate zoögonidia.

M. Wittrockii (Wille) Lag., Fig. 216.

M. Stagnorum (Kütz.) Lag., Fig. 92.

[*M. abbreviata* (Rab.) Lag.; *M. amœna* (Kütz.) Rab.; *M. crassior* (Hansg.) Haz.]

FAMILY V. HERPOSTEIRACEÆ.

The thallus is a creeping filament, sometimes branched, and growing on larger Algæ or other water plants; most of the cells have a bristle on the back, which is bulbous at the base and separated from the cell by a septum.

In the sexual reproduction, cells in the centre of the thallus, devoid of bristles, form the oögonia. One oösphere is formed in each oögonium, and is ejected through an opening in the wall. The oösphere is large and slowly motile, provided with four cilia. Smaller cells on the end of the thallus, frequently colorless, form the antheridia. One or two swiftly moving antherozoids, pear-shaped, each with four cilia and two pulsating vacuoles, are produced in each antheridium, and they unite, outside the oögonium, with the oösphere.

Herposteiron Näg. (**Aphanochæte** A. Br., Berth., Huber).— Coextensive with the family.

H. Confervicola Näg., Fig. 80*b*.

[*H. vermiculoides* Wolle.]

FAMILY VI. CHÆTOSPHÆRIDIACEÆ.

Thallus creeping, composed of flask-shaped cells more or less loosely joined, and each bearing a very long and slender seta, sheathed at the base. Cell division horizontal, the lower daughter-cell migrating to the side.

Asexual reproduction by zoöspores, formed to the number of four or more (?) in a cell.

Chætosphæridium Klebahn.— Coextensive with the family.

FAMILY VII. COLEOCHÆTACEÆ.

Small, bright green water-plants. The thallus forms small green cushions or discs. The cells in the common species often

form a flat, more or less circular plane, or are arranged as filaments radiating from one point. The cells are oblong, more or less dilated at the anterior end, and some of them bear a colorless bristle fixed in a long and narrow sheath.

The oögonium is round, on a slender neck — the continuation of the end cell of the plant. Antheridia found either on a neighboring cell or on a separate thallus. The oöspore rests for the winter, and develops in the following spring. Asexual reproduction by zoögonidia, which are larger than the antherozoids and may be developed in any cell.

Coleochæte Breb.— Coextensive with the family.

C. irregularis Pringsh. (?), Fig. 80*a*.

C. scutata Breb., Fig. 243.

ORDER V. ŒDOGONIALES.

Thallus of simple or branched filaments, fixed. The cells are uninucleate, and with a parietal, more or less anastomosing chloroplast containing one or more pyrenoids. In the vegetative division new pieces of the cell wall are intercalated. The zoögonidia are possessed of a circle of numerous cilia around the anterior end. Antheridia and oögonia are present.

FAMILY I. ŒDOGONIACEÆ.

Filaments branched or unbranched, attached in early stages. Cell multiplication by transverse division, shown by transverse striæ, usually at the end of the mother-cell.

The oögonia are developed in a series of vegetative cells, and are at first green, then orange, and finally dark red or almost black. There are two kinds of male plants, dwarf and elongated; the dwarf males are attached to female plants, and the elongated males are composed of a short series of cells forming an independent thread.

Asexual reproduction by zoögonidia. The entire contents of a cell gather in one mass, the cell wall splits near one end, and the mass, with a small colorless protuberance on one end surrounded by numerous cilia, escapes and swims away to form a new plant.

Key to Genera.

Cells long, without a laterally placed bristle. *Œdogonium**

Cells short, with a laterally placed bristle.... *Bulbochæte**

Description of Genera.

Œdogonium Lk.— Filaments simple, articulate; the end cell sometimes setiform, sometimes with an acute conical cap; cells enlarged at the upper extremities. The oögonia and antheridia are either on the same or on different filaments. Dwarf males, shaped like inverted flasks, are parasitically situated near the oögonium. The elongated males are independent and shorter than the female plant. When a cell has reached maturity, it splits below the top by a circular line, the top is raised by growth, and a new cell formed. This may split again, and a new growth push the top up and leave another ring; this may be repeated five or six more times, leaving a new ring each time.

O. sp. (?), Fig. 96.

O. cardiacum (Hass.) Wittr. (?), Fig. 228. Male and female specimens.

[*O. crenulato-costatum* Wittr.]

Bulbochæte Ag.— Filaments much branched; almost all the cells thickened upwards, and bearing on that end long, thin, transparent bristles, bulbose at the base. Reproduction as in *Œdogonium*. The plants are more often mixed than in *Œdogonium*, and are enveloped in a quantity of mucus.

B. sp. (?), Figs. 97, 98.

[*B. intermedia* DeBary.]

ORDER VI. CLADOPHORALES.

Three families, very like the *Siphonales*, comprise this order. The thallus is simple or branched, incompletely divided into cells. Each portion contains many nuclei and parietal chloroplasts, with single pyrenoids. Asexual reproduction by resting spores, cysts, or zoögonidia with two or four cilia. Sexual reproduction by heterogamous or isogamous gametes.

The order is divided into families, as follows:—

Key to Families.

1. Filaments unbranched, compound or elongated cœnocytes .... SPHÆROPLEACEÆ
   Filaments branched 2

2. Producing barrel-shaped and fusiform resting spores PITHOPHORACEÆ

Without the barrel-shaped resting spores......... CLADOPHORACEÆ

FAMILY I. SPHÆROPLEACEÆ.

The thallus is unbranched, composed of cells from one to ninety times as long as wide, each with several nuclei, and parietal chloroplasts in the form of rings. Any segment of the filament may form an oögonium or a bright red antheridium. These sometimes alternate in a filament. Many antherozoids are formed on the breaking up of the antheridium, and they penetrate the oögonium through the transverse walls. Bright red oöspores with thick walls are produced, which hibernate in the oögonium, and on germination from two to eight zoöspores are set free, which produce young plants, simple, fusiform, attenuated to a fine point on each end.

Sphæroplea Ag.— Coextensive with the family. Its filaments are 36-62 microns in diameter.

FAMILY II. PITHOPHORACEÆ.

Thallus much branched, segments six to twelve or more times longer than broad. Usually many nuclei in a segment, chloroplast parietal; growth apical; attached below by a rhizoid. Asexual, green resting spores with thick walls are produced here and there; when intercalated, cask-shaped; when terminal, ovoid or fusiform. They develop on germination at both ends.

Pithophora Wittr.— Coextensive with the family. It is almost exclusively tropical.

FAMILY III. CLADOPHORACEÆ.

Thallus large, filamentous, incompletely septate, branched in *Cladophora*. Each segment contains several nuclei and one reticulated parietal chloroplast or several smaller ones, each with a pyrenoid. In *Cladophora* and *Chætomorpha* asexual reproduction is by zoögonidia, formed in great numbers in the mother-cell. *Rhizoclonium* produces thick-walled cysts. *Cladophora* has also an isogamous sexual reproduction.

The *Cladophoraceæ* secrete very little or no mucus, and are, therefore, a resting place for epiphytes.

Key to Genera.

1. Filaments unbranched; cells often slightly swollen *Chætomorpha*
   Filaments commonly branched; cells not swollen... 2
2. With branched rhizoids ....*Rhizoclonium**
   Without rhizoids ....*Cladophora**

Description of Genera.

Chætomorpha Kütz.— Wide, simple filaments of thick-walled, swollen segments; fixed at the base, the basal segments being shorter than the rest. The cell wall is firm and lamellose. Mostly marine or in brackish water.

Rhizoclonium Kütz.— Filaments slightly branched, with branched rhizoids at the base; articulate, somewhat contorted, having here and there short branches composed of from one to three cells.

[*R. lacustre* forma *Americanum* Wille; *R. hieroglyphicum* var. *macromeres* Nordst.]

Cladophora Kütz.— Filaments much branched, the last branches much thinner than the main stem; cell walls thick, cells longer than broad. Propagation by zoögonidia, which develop in large numbers within the cells.

C. glomerata (L.) Kütz., Fig. 274.

[*C. callicoma* Kütz.]

ORDER VII. SIPHONALES.

Plant composed of an elongated cœnocytic filament (*cœnocyte*), which is much branched. The order inhabits salt water almost exclusively. The only family living in fresh water is the *Vaucheriaceæ*.

FAMILY I. VAUCHERIACEÆ.

Thallus elongated, somewhat branched, cœnocytic, usually attached. The protoplasm contains many minute nuclei. The oval chloroplasts are small and numerous. The cell wall is thin and easily broken; after which the injured part is cut off by a septum, and the uninjured parts develop into new plants.

Vaucheria D. C.— Many filaments growing from one root, green, rather stout. A single filament usually more or less branched, with chlorophyll quite evenly distributed on the inside of the cell wall, forms one plant. Sexual reproduction by oöspheres and spermatozoids; asexual reproduction by zoöspores. One zoöspore, provided with many cilia, is formed in a swelling at the tip of the thallus, cut off from the rest of the cell by a wall. The oögonia and antheridia, either sessile or on short pedicles, grow in various numbers on the same tube and usually close together.

V. sessilis (Vauch.) D. C., Figs. 200, 201. Sexual organs of this species are shown in Fig. 206.

[*V. aversa* Hass.; *V. geminata* (Vauch.) D. C.]

ORDER VIII. CONJUGATÆ.*

The *Conjugatæ* are green or brownish Algæ, sometimes single-celled, but usually composed of many cells closely joined. They are named from the peculiar mode of propagation. Two cells unite their entire contents to form a zygospore; rarely two zygospores result from such a union. Resting spores or cysts are produced in the *Zygnemaceæ* without copulation. Non-motile spores are sometimes formed. All the *Conjugatæ* are very slimy to the touch.

Key to Families.

Unicellular; cells commonly constructed of two symmetrical halves; of very many forms, though rarely cylindrical; single, or, very rarely, bound together in a loose thread; two to eight germs develop from a single zygospore.......... DESMIDIACEÆ

Thallus a thread of many similar cells; each zygospore produces only one germ plant..... ZYGNEMACEÆ

* Our work upon the remaining orders of Chlorophyceæ is as yet quite incomplete. These Algæ are abundant in our waters. In the filamentous forms it is difficult or impossible to identify the species from the vegetative stages; and, since in ordinary waters it is usual to find these stages only, specific determination is frequently impossible. The family of *Desmidiaceæ* is very abundant; and, while our list contains a large number of them, doubtless a longer study will show many more species. The common species are, however, fairly well represented.

FAMILY I. DESMIDIACEÆ.

Cells of various forms, but symmetrical, single, or, in a few genera, loosely united into threads. Often a constriction in the middle of the cell divides it into halves, called semi-cells; the cell contents nearly always divided. The cell wall is often provided with granules, spines, or other protuberances, which are usually arranged in a definite pattern. These projections serve as a protection from aquatic animals, and as an anchor in times of flood. Conjugation of two cells results in zygospores. Asexual multiplication by transverse division or separation of semi-cells. The *Desmidiaceæ* are surrounded by a mucus exuded through pores in the cell wall, and often may be found embedded in a mass of jelly.

They are not free-swimming, but are able under certain conditions of light and gravitation to glide along a hard surface.

Desmids are extremely abundant the world over; there are several thousand known species, living in all degrees of temperature, and found most abundantly in soft water.

The following key, modified from West, includes all the known genera of Desmids, four of which (*Ichthyocercus, Triploceras, Phymatodocis,* and *Streptonema*) are exclusively tropical, and one (*Ancylonema*) is exclusively arctic. We have identified certainly as yet only a part of the Connecticut species, but have indicated by an asterisk the genera, and have figured the species thus far observed.

Key to Sub-families.

Cell wall not evidently divided into two parts, and without pores.......................... SACCODERMÆ

Cell wall showing two segments, and with a differentiated outer porous layer............... PLACODERMÆ

SUB-FAMILY I. SACCODERMÆ.

Cell wall unsegmented and without pores. Point of division of cells indefinite, and unknown previous to the actual division. The young half of the cell is developed obliquely, and its walls are absolutely continuous with the walls of the older half.

Key to Tribes and Genera.

TRIBE I. GONATOZYGEÆ. Cells elongate, cylindrical, and unconstricted, forming loose filaments. Cell wall with a differentiated outer layer, of which the small roughnesses and spines form a part.

Chloroplasts axile........................*Gonatozygon*
Chloroplasts parietal and spirally twisted....*Genicularia*

TRIBE II. SPIROTÆNIEÆ. Cells solitary, relatively short, and mostly unconstricted. Cell wall a simple sac, without a differentiated outer layer. The cell becomes adult by periodical growth.

1. One chloroplast in each cell...................... 2
   Two chloroplasts in each cell..................... 4
2. Chloroplast spirally twisted, axile or parietal..*Spirotænia*
   Chloroplast plane, axile........................ 3
3. Cells solitary..........................*Mesotænium**
   Cells forming short filaments..............*Ancylonema*
4. Chloroplasts star-shaped, radiating from a central pyrenoid ....*Cylindrocystis*
   Chloroplasts ridged with longitudinal serrated ridges *Netrium**

Description of Genera.

Gonatozygon D. By.— Cells long and straight, not constricted, forming filaments which break up at maturity. The cell wall is smooth or covered with minute granules. The two chloroplasts are axile, thin and waving or twisted; they contain four to sixteen equidistant pyrenoids. The zygospores, which quickly separate from the empty cells, are smooth.

Spirotænia Breb.— Cells straight, fusiform, ends rounded, not constricted in the middle; cells single or several, covered by a gelatinous envelope. Chloroplasts spiral bands on the inside of the cell wall.

Mesotænium Näg.— Cylindrical cells, straight or slightly curved, without median constriction. The ends are broadly rounded. The chloroplast is a flat plate, extending from one end of the cell to the other; occasionally there are two chloroplasts.

M. micrococcum (Kütz.) Roy and Biss., Fig. 219.

Netrium Näg.— Cylindrical, straight, or fusiform cells, without constriction. Chloroplasts two (or four) in each cell, each with longitudinal serrate ridges.

N. interruptum (Breb.) Lutkem, Fig. 281.

N. Digitus (Ehrb.) Itz. and Roth., Fig. 282.

SUB-FAMILY II. PLACODERMÆ.

Cell wall mostly constricted, with a differentiated outer layer. Cell division follows a fixed type, with interpolation of the younger halves between the old ones. The younger portions of the cell wall are joined to the older portions by an oblique surface.

Key to Genera.

1. After division the cells remain free and solitary.... 2
   After division the cells remain attached to form colonies 14
2. Cells more or less constricted at the middle........ 5
   Cells not constricted............................ 3
3. Cells of moderate length, straight, cylindrical...*Penium**
   Cells elongate, generally curved and attenuated..... 4
4. Cells almost cylindrical, scarcely attenuated; chloroplast single, without apical moving granules....*Roya**
   Cells strongly attenuated towards each extremity; two chloroplasts in each cell, with apical moving granules ....*Closterium**
5. Cells elongated and cylindrical, constriction slight.. 6
   Cells relatively short; deeply constricted.......... 10
6. Apices of cells truncate or rounded, entire........ 7
   Apices of cells cleft, incision open or narrow....... 8
7. Base of semi-cells plicate...................*Docidium**
   Base of semi-cells plane................*Pleurotænium**
8. Cell wall adorned with rings of furcate processes.. *Triploceras*
   Cell wall plane 9
9. Apical incision widely open, each apical angle furnished with a spine.................*Ichthyocercus*
   Apical incision narrow..................*Tetmemorus*
10. Cells compressed (at right angles to the plane of the

front view), in the vertical view fusiform or elliptical 11
Cells in vertical view radiating, triangular, quadrangular, or radiate; rarely fusiform......*Staurastrum**
11. Cells mostly oblong or elliptical; moderately lobed; margins wavy, the depressions rounded....*Euastrum**
Cells very much compressed, mostly orbicular or broadly elliptical, deeply lobed or incised.*Micrasterias**
Cells with a more or less entire margin, often furnished with warts or spines................. 12
12. Cell wall with regularly arranged spines of considerable length 13
Cells without spines.......................*Cosmarium**
13. Spines several, commonly in pairs; a central protuberance always present................*Xanthidium**
Spines 4 or 8, occasionally 16, no central protuberance *Arthrodesmus**
14. Colonies spheroidal; cells not in contact, but joined by gelatinous bands.......................... 15
Colonies thread-like; cells attached by their apices to form long filaments.......................... 16
15. Gelatinous bands narrow; few cells forming a microscopic colony.......................*Cosmocladium*
Gelatinous bands very broad, many cells forming a macroscopic colony.......................*Oöcardium*
16. The line of division of the cell, where the new and old parts of the cell wall are obliquely fitted together, develops a girdle during division......... 21
The line of division does not develop a girdle during division 17
17. Cells attached by special apical processes.......... 18
Apices of cells plane and flat..................... 19
18. Apical processes very short.............*Sphærozosma**
Apical processes long and overlapping the apices of the adjoining cells ....*Onychonema**
19. Cells deeply constricted........................ 20
Cells slightly constricted..................*Hyalotheca**
20. Cells in vertical view elliptical..........*Spondylosium**
Cells in vertical view quadrangular with produced angles ....*Phymatodocis*

21. Cells joined by special apical processes.....*Streptonema*
Cells joined by their flat apices or by flattened apical projections 22

22. Cells short, in vertical view fusiform, triangular, or quadrangular (rarely circular with produced angles) ....*Desmidium**
Cells elongate, cylindrical..................*Gymnozyga*

Description of Genera.

Penium Breb.— Cells straight, cylindrical or fusiform, without median constriction, ends rounded; free or collected in a gelatinous membrane. Cell wall smooth, or minutely granular, colorless or sometimes red, often finely striate. Chloroplast axile; when seen in cross section star-shaped, with arms often forking. Multiplication by division, and by zygospores formed by conjugation.

P. closterioides Ralfs, Fig. 172.

P. polymorphum Perty, Fig. 173.

P. margaritaceum (Ehrb.) Breb., Fig. 175.

P. Navicula Breb., Fig. 218.

Roya West.— Cells curved but not attenuated. Cell wall without pores, chloroplast single, without dancing granules.

R. obtusa (Breb.) West, Fig. 145.

Closterium Nitzsch.— Cells simple, elongated, crescent-shaped or lunately curved, entire. The centres are not constricted, but often bear a few transverse striæ. The cell walls are smooth or finely striate, colorless or brown; at each end of the cell is a vesicle, colorless or straw-colored, containing numerous granules. The chloroplasts are arranged in longitudinal rows broken in the middle by a transverse, colorless band.

C. acuminatum Kütz., Fig. 147.

C. lanceolatum Kütz., Fig. 148.

C. Cucumis Ehrb. (?), Fig. 149.

C. *acerosum* (Schrank) Ehrb. (?), Figs. 150, 151.

C. Lunula Ehrb., Fig. 152.

C. turgidum Ehrb., Fig. 153.

C. strigosum Ehrb., Fig. 154.

C. costatum Corda, Fig. 155.

C. Delpontei Klebs, Fig. 156.

C. prelongum (Breb.) Delp., Fig. 157.
C. lineatum Ehrb., Figs. 157*a*, 158.
C. decorum Breb., Fig. 159.
C. areolatum Wood, Fig. 161.
C. Dianæ Ehrb., Fig. 162.
C. Jenneri Ralfs, Fig. 160.
C. parvulum Näg., Figs. 163, 164.
C. moniliferum (Bory) Ehrb., Fig. 165.
C. Leibleinii Kütz., Fig. 166.
C. Leibleinii var. *curtum* West, Fig. 167.
C. rostratum Ehrb., Fig. 168.
C. rostratum var. *brevirostratum* West, Fig. 169.
C. subcostatum Nord., Fig. 170.
C. Brébissonii Delp., Fig. 171.

Docidium Breb.— Cells straight, cylindrical or fusiform; ends rounded, truncate or smooth, constricted in the middle; each semi-cell furnished with a basal inflation. The base is plicate with a granule under each plication. Chlorophyll axile and an axile row of pyrenoids. The ends have a vacuole containing dancing granules.

D. Baculum (Breb.), Figs. 103, 223.
D. verticillatum (Bailey) Ralfs, found but not figured.

Pleurotænium Näg.— In shape much like *Docidium*, without plications at the base of the semi-cells. The ends are truncate and usually furnished with a ring of tooth-like projections. The parietal chloroplasts are longitudinal and are provided with several pyrenoids. The centre of the cells usually contains large vacuoles, and in the apical ones moving granules are often seen.

P. crenulatum (Ehrb.) Rab., Fig. 224.
P. Archerii Delp., Fig. 225.
P. Trabecula (Ehrb.) Näg., Fig. 226.
P. nodosum (Bail.) Lund., Fig. 283.
P. sp. (?), Fig. 101.

Tetmemorus Ralfs.— Cells like *Penium*, except that the ends are slightly cut and the middle is constricted. One central chloroplast with a single row of pyrenoids is present. Cell wall mostly punctate or granulose.

Staurastrum Meyen.— The second largest genus of Desmids. Cells in front view oblong, cylindrical, elliptical, or orbicular, with margins notched or smooth, always constricted in the middle, ends rounded, entire. End view with three to six obtuse, acute, or horn-like angles. Chlorophyll more or less central, zygospores commonly furnished with spines (see Fig. 261).

S. orbiculare (Ehrb.) Ralfs, Figs. 123, 124.
S. dejectum (Breb.) var. *convergens* Wolle, Fig. 122.
S. dejectum var. *mucronatum* Ralfs, Fig. 125.
S. megacanthum Lund., Figs. 126, 127.
S. hirsutum (Ehrb.) Breb., Figs. 133, 263, 263*a*.
S. brevispinum Breb., Fig. 128.
S. leptocladum Nord., Figs. 264, 264*a*.
S. erasum Breb., Figs. 130, 131.
S. arctiscon Ehrb., Figs. 268, 268*a*.
S. odonatum Wolle, Fig. 132.
S. coronulatum Wolle, Figs. 267, 267*a*.
S. Ravenelii Wood, Figs. 134, 135.
S. dejectum Breb., Figs. 233, 236.
S. furcigerum Breb., Fig. 136.
S. crenulatum (Delp.) Näg., Fig. 231.
S. margaritaceum Ehrb., Fig. 235.
S. iotanum Wolle, Fig. 143.
S. eustephanum Ralfs, Fig. 144.
S. pygmæum Breb., Fig. 261. Conjugating.
S. muricatum Breb., Fig. 129.
Four species, names unknown, Figs. 137-142.
S. gracile Ralfs, found but not figured.

Euastrum Ehrb.— Cells elliptical or oblong, deeply constricted; semi-cells usually cut at the ends and wavy or lobed at the sides, the number of lobes being uneven; usually furnished with circular inflated protuberances.

E. integrum Wolle, Fig. 105.
E. verrucosum (Ehrb.) Ralfs, Fig. 104.
E. oblongatum (Grev.) Ralfs, Fig. 229.
E. ampullaceum Ralfs, Fig. 230.
E. elegans Kütz., Fig. 232.
E. Nordstedtianum Wolle, Fig. 234.

E. sp. (?), Fig. 227.

E. ansatum (Ehrb.) Ralfs, found but not figured.

Micrasterias Ag. (**Holocystis** Hass.; **Tetrachastrum** *Dixon*).— Cells simple, flattened, in the form of a double-convex lens, deeply constricted in the middle. Front view orbicular or broadly elliptical; end view spindle-shaped, with acute ends. Each semi-cell three- to five-lobed; lateral lobes entire, or irregularly cut into large, deep lobes; the end lobes entire, or more slightly cut, sometimes with angles pronounced, and two-cleft. Zygospores seldom found, large, globular, with stout spines which are at first simple and later branched.

M. radiosa (Ag.) Ralfs var. *punctata* West, Fig. 106.

M. apiculata Menegh., Fig. 108.

M. rotata (Grev.) Ralfs, Fig. 238.

M. furcata (Ag.) Ralfs, Fig. 239.

M. Americana (Ehrb.) Kütz., Fig. 240.

M. muricata Bailey, Fig. 241.

M. truncata (Corda) Ralfs, Fig. 242.

M. Crux-Melitensis (Ehrb.) Hass., Fig. 107.

Arthrodesmus Ehrb.— Cells simple, deeply constricted in the middle; each half-cell is wider than long, and furnished with several spines. This genus is distinct from *Xanthidium* by the absence of the protruding area in the centre of the semi-cells. There are usually fewer spines, and the zygospores are either smooth or spinous.

A. octocornis Ehrb., Fig. 260.

A. convergens (Ehrb.) Ralfs, Fig. 259.

Cosmarium Corda (**Dysphinctium** Näg.; **Calocylindrus** (Näg.) Kirch.; **Cosmaridium** Gay; **Pleurotæniopsis** (Lund.) Lagerh.).— The largest genus of Desmids. The single cells circular, elliptical, or oblong, usually one and one-half diameters in length, always more or less constricted in the middle. Ends usually entire, rounded or truncate. The margins are smooth, dentate, or crenate, the cell wall smooth, punctate, warty, or even covered with spines. End view oblong or oval, with sometimes a swelling in the middle of the longer sides. Zygospores usually spherical, sometimes cubical or angular, smooth or furnished with spines.

C. Botrytis Menegh., Figs. 115, 116.
C. Broomei Thwaites, Figs. 99, 258.
C. suborbiculare Wood, Fig. 113.
C. granatum Breb., Fig. 109.
C. crenatum Ralfs, Fig. 110.
C. contractum Kirch., Fig. 117.
C. tumidum Lund., Figs. 100, 100a.
C. ornatum Ralfs, Fig. 102.
C. ovale Ralfs, Fig. 245.
C. undulatum Corda, Fig. 244.
C. pyramidatum Breb., Fig. 246.
C. Meneghinii Breb., Fig. 247.
C. octhodes Nord., Fig. 248.
C. perforatum Lund., Fig. 249.
C. Nägelianum Breb., Fig. 250.
C. intermedium Delp., Fig. 251.
C. Portianum Arch., Fig. 252.
C. orbiculatum Ralfs, Fig. 253.
C. tetrophthalmum (Kütz.) Breb., Fig. 254.
C. galeritum Nord., Fig. 255.
C. Cucurbita Breb., Fig. 256.
C. pseudobroomei Wolle, Fig. 257.

Xanthidium Ehrb.— Cells single, or two joined end to end; deeply constricted; semi-cells wider than long, entire, furnished with spines, and with a round, truncate, or toothed arm projecting from the centre. The spines are either simple or with two or three forks at the end. In the centre of each semi-cell is a roughened protruding area of variable size. Zygospores spherical and spinous.

X. fasciculatum (Ehrb.) Ralfs var. *subalpinum* Wolle, Figs. 121, 266.
X. antilopæum (Breb.) Kütz., Fig. 262.
X. cristatum (Breb.) Ralfs, Fig. 265.
X. aseptum Nord., found but not figured.

Sphærozosma Corda.— Filaments of cells closely united by a narrow isthmus or by a granular process. Cells deeply constricted, thus forming bilobed cells.

S. filiforme Rab., Figs. 118, 119.

S. spinosum Delp., Figs. 120, 277.
S. pulcrum Bailey, Fig. 271.

Onchonema Wall.— Like *Sphærozosma* except that the granular processes are long.

O. serratum (Bailey) Wall., Fig. 272.

Hyalotheca Ehrb.— Cells short, cylindrical, usually blunted, constricted in the centre; joined in long filaments enclosed in an ample mucilaginous sheath. The end view of the cell is round and shows the chloroplast to be eight- to ten-rayed.

H. dissiliens (Sm.) Breb., Fig. 273.

Spondylosium Breb. (**Leuronema** Wallich).— Like *Sphærozosma* except that instead of being united by lateral processes, the cells are joined in filaments merely by the close apposition of the cells.

S. papillatum West, found but not figured.

Desmidium Ag. (**Didymoprium** Kütz.; **Aptogonum** *Ralfs*).— Cells incised or entire, with two chloroplasts barely touching in the middle; triangular or quadrangular in end view; united into fragile, elongated filaments, regularly twisted, and enclosed in a mucous envelope.

D. cylindricum Grev., Fig. 276.
D. Swartzii Ag., Fig. 275.

Gymnozyga Ehrb. (**Bambusina** Kütz.).— Cells barrel-shaped with one or more narrow bands around the middle; closely united into articulate filaments. Chlorophyll bodies as in *Hyalotheca*. Zygospores smooth, ellipsoidal.

FAMILY II. ZYGNEMACEÆ.

Unbranched filaments composed of single cells or of a simple series of cells. Chloroplasts in the shape of spiral bands, axile plates, or twin stellate bodies.

Key to Sub-families.

Conjugation producing a zygospore which, after a period of rest, develops directly into a new gametophyte ....ZYGNEMEÆ

Conjugation producing a zygospore which immediately develops a sporocarp of several cells, one of which is the spore. The gametophyte is developed from this spore after a period of rest....MESOCARPEÆ

SUB-FAMILY I. ZYGNEMEÆ.

Filaments unbranched. A lining of protoplasm is in each cell, and the nucleus is held in the centre by quite prominent bands of protoplasm. The chloroplasts containing numerous prominent pyrenoids are twin stellate bodies in *Zygnema* and spiral bands in *Spirogyra.*

Vegetative multiplication by breaking of filaments into separate cells or groups of cells. Asexual reproduction by spores. Sexual reproduction by conjugation between cells of different filaments which lie close together. Each cell puts out a tube on the side nearest the other filament, and these meet with similar tubes from the cells of the other filament. The ends of the tubes join, and an open "conjugating tube" is formed. The contents of the cells separate from the cell walls, and the mass from one cell flows into the other, there to unite with the mass in that cell and form a zygospore. The zygospores are usually all found in one of the two filaments. Occasionally lateral conjugation between two cells of the same filament is observed.

Key to Genera.

Cells containing two star-shaped chlorophyll bodies near the nucleus........................*Zygnema**

Cells with spirally twisted bands of chlorophyll... *Spirogyra**

Cells with nearly straight bands of chlorophyll.*Choaspis**

Description of Genera.

Zygnema Ag. (**Zygogonium** Kütz.).— Cells with two star-shaped chlorophyll bodies near the nucleus, each chloroplast bearing a starch grain.

Z. leiospermum D. By., Fig. 176.

Z. stellium Ag., Figs. 177, 178.

Z. stellium var. *genuinum* Kirch., Fig. 179.

Z. pectinatum (Vauch.) Ag., Fig. 279. In conjugation.
Z. cruciatum (Vauch.) Ag., Fig. 180.

Spirogyra Link.— Cells with from one to many bands of chlorophyll in the cell wall, winding to the right. The zygospores are always inside the walls of one of the conjugating cells.

The length and width of the cells, the form of the dividing wall (which may be plane or replicate, *i. e.,* with an annular ingrowth of cellulose), the number of spirals, and the number of turns each spiral makes in a cell, are all points for consideration; but the zygospores form the only decisive factor in the determination of species. In the determination of the species given below, we have chiefly relied on the vegetative thread.

Found in low-lying ponds and ditches.

S. varians (Hass.) Kütz., Figs. 181, 182.
S. Weberi Kütz., Figs. 183, 184.
S. maxima (Hass.) Witt., Fig. 185.
S. jugalis (Dillw.) Kütz., Figs. 186, 187.
S. inflata (Vauch.) Rab., Fig. 269.
S. calospora Cleve, Fig. 195.
S. dubia Kütz., Fig. 188.
S. quinina (Ag.) Kütz., Figs. 189, 190.
S. Grevilleana (Hass.) Kütz., Fig. 191.
S. majuscula Kütz., Fig. 192.
S. adnata Kütz., Fig. 193.
S. Spreeiana Rab., Fig. 194.
S. decimina (Müll.) Kütz., Fig. 196.
S. communis (Hass.) Kütz., Fig. 197.
S. fluviatilis Hilse, Figs. 198, 199.
S. mirabilis Hass., Fig. 202.
S. bellis (Hass.) Cleve, Figs. 203, 204, 270.
S. flavescens (Hass.) Cleve, Fig. 205.
S. crassa Kütz., Fig. 60.
[*S. nitida* (Dillw.) Link.]

Choaspis S. F. Gray (**Sirogonium** Kütz.).— Filamentous. The only genus of Conjugatæ without a mucous coat. Sterile cells much like *Spirogyra;* conjugating cells arise by unequal division of the cells of the filaments, and,

bending knee-like towards each other, grow together; zygospores elliptical.

SUB-FAMILY II. MESOCARPEÆ.

The plants of this sub-family are often narrower than those of Zygnemeæ, with thin cell walls. The chloroplast is a thin axile plate, and all those of a filament usually lie in one plane. The chloroplasts change their position according to the degree of light, turning the edge to bright light and the face to dim light. Reproduction as in Zygnemeæ.

Key to Genera.

Plants reproducing by conjugation.........*Mougeotia**
Reproduction by non-sexual methods only..*Gonatonema*

Description of Genera.

Mougeotia A. Br. (**Staurospermum** Kütz.; **Mesocarpus** Hass.; **Craterospermum** Braun; **Plagiospermum** Cleve).—Cells long, cylindrical, with axile chloroplasts. Conjugation scalariform; zygospores spherical or quadrate and more or less flattened with rounded angles.

M. sp. (?), Fig. 85. The method of conjugating is shown in Fig. 280.

[*M. robusta* (De Bary) Wittr.; *M. genuflexa* (Dillw.) Ag.]

Gonatonema Wittr.—Cells similar to *Mougeotia,* but reproduction only by means of non-sexual spores. Spores produced without conjugation, formed by division of the mother-cells, which are afterwards often burst and bent angularly and alternately at the point of fructification.

CLASS V. CHARACEÆ.

Algæ with a peculiar odor; often encrusted with lime. Thallus a stem with nodes and internodes. The plants grow from a few inches to over a foot in height by means of an apical cell. Whorls of leaves, on which may be borne antheridia and oögonia, grow at the nodes.

Zoöspores are wanting. The organs of reproduction are conspicuous in color and form. The antheridia are spherical,

red when mature, the wall consisting of eight shields or plates. The spermatozoids are spirally coiled. The oögonium is situated on a nodal cell from which five other cells grow and coil around the oögonium, covering it closely. They divide once or twice at the top, so that a crown of five or ten small cells is formed.

Description of Genera.

Chara Vaill.— The crown consists of five cells. The stems are covered with a cortex.

C. sp. (?), Figs. 207-209.

Nitella Ag.— The crown consists of ten cells; cortex lacking.

CLASS VI. PHÆOPHYCEÆ (FUCOIDEÆ).

The Algæ of this class are almost exclusively salt-water forms, known as the Brown Seaweeds, and include the most highly developed of the Seaweeds. The vegetative cells are uninucleate, and the chromatophores are distinctly brown.

Asexual reproduction by means of motile cells or zoögonidia. Sexual reproduction by isogamous or heterogamous gametes. Copulation always takes place outside the plant, and the resulting spore germinates directly. The motile cells always possess two laterally placed cilia, one directly forward and the other backward.

While the class is made up mostly of marine plants, there is one order that is found in fresh water.

ORDER I. SYNGENETICÆ.

Exclusively fresh-water forms. Plants unicellular, solitary or colonial, or multicellular; free-swiming or motionless. The cells are either naked or surrounded by a mucilaginous envelope. The cells are uninucleate, possess one or more pulsating vacuoles, one or two yellow or pale brown chromatophores, and occasionally pyrenoids.

The order as thus defined includes about seven families. But at least four of the seven are frequently classed with the Flagellate Protozoa, and are described in the report upon the Protozoa of our waters. These include the following genera:

Cryptomonas, Synura, Uroglena, Dinobryon. (See Bull. No. 2 of this Survey.)

The only other family known to us to occur in our fresh water is the following: —

FAMILY I. HYDRURACEÆ.

The plant consists of an attached colony, from two to twelve inches long. The cells have each one chromatophore, lack a cell wall, and are embedded in a large mass of jelly. Cells brown at one end, colorless at the other; arranged in irregular, longitudinal families; at first globose, then elliptical. Division at first in one, later in two directions.

Asexual reproduction by uniciliated tetrahedral zoögonidia. Two or four of them are produced from each cell of the branches, and germinate at once. Resting spores have been observed.

Hydrurus Ag.— Coextensive with the family.

CLASS VII. RHODOPHYCEÆ (FLORIDEÆ).

Plants generally rosy red or purple, dark reddish-brown, or blackish. Most closely related to salt-water Algæ. Crustaceous, filamentous, variously branched.

Asexual propagation by means of motionless spores. In the sexual reproduction, which is wanting in some of the genera, the female cell, called the *carpogonium*, is fertilized by a mass of protoplasm, called *spermatium,* derived from a male cell. The result of fertilization is called a *cystocarp,* and the method of its formation determines the different groups of Rhodophyceæ.

Sometimes the cystocarp is developed directly, and sometimes the fertilized carpogonium puts out growths, known as *oöblastema-filaments,* which conjugate with auxiliary cells, the result being the cystocarp. The carpospores are always developed on a tuft of filaments which spring from the fertilized cells and are called *gonimoblasts.*

Of the four orders of this class, two are found in fresh water. They are distinguished as follows:

Key to Orders.

Carpogonium developing directly......NEMALIONALES
Carpogonium developing a filament of which two cells conjugate with each other....CRYPTONEMIALES

ORDER I. CRYPTONEMIALES.

A long branched filament is sent out from the fertilized carpogonium. Each terminal cell of the filament unites with an auxiliary cell, and from the latter the gonimoblasts arise.

FAMILY I. SQUAMARIACEÆ.

A small group, mostly marine, but with a few fresh-water species. The thallus consists of dense, upright cell-filaments, which form minute, flat, gelatinous or membranous expanses. Cavities in the upper surface of the thallus hold the sexual organs, and, after the fertilization of the carpogonia, are filled with cystocarps.

Hildenbrandtia Nardo.— Thallus crustaceous, firmly adhering, formed of subcubical, blood-red, dark red, rose, or brown cells, placed in close vertical series. Sexual organs in cavities in the upper surface.

ORDER II. NEMALIONALES.

The gonimoblasts are developed in tufts, directly from the fertilized carpogonium.

Key to Families.

Thallus with a basal attached portion, from which arise tufts of simple or branched filaments..... LEMANEACEÆ
Thallus filamentous, simple or branched, with secondary axes often in whorls...HELMINTHOCLADIACEÆ

FAMILY I. LEMANEACEÆ.

Exclusively fresh-water Algæ, growing in very rapid water. The thallus consists of a basal attached portion from which arise dense tufts of erect branched filaments. From these grow the fructiferous branches which are the most conspicuous part of the plant. After the growth of this part, the

vegetative portion of the thallus generally dies away, and these branches become fixed by rhizoids of their own. The fructiferous branches are long, filamentous, cartilaginous, and swing freely in the water; they are olive-green or greenish black. Each thread is built up of an axile row of tubular cells surrounded by rows of smaller cells; at short, more or less regular, distances along the entire length are distinct swellings or nodes.

Only sexual multiplication is known. The antheridia are short and cylindrical, growing on whorled eminences or on the widest part of the nodes. The carpogonium possesses a long, simple or branched process for the reception of the male gamete, called a *trichogyne*. After fertilization the carpogonium puts out an oöblastema-filament, at the extremity of which a bunch of jointed moniliform filaments arises, each of the swollen cells of which becomes at maturity a carpospore. The carpospores are produced on the inside of the thallus, filling up the space between the axile cells and the cortical cells. The carpospores in turn produce the vegetative thallus.

Lemanea Bory.— Large, simple or somewhat branched, bristle-like threads of dark or brownish color; hollow except for the axile series of cells which is held in place by transverse threads at regular intervals.

[*L. fucina* var. *rigida* (Sirdt.) Atk.]

Tuomeya Harvey.— Thallus much branched, upright, five cm. high, rosette-like.

[*T. fluviatilis* Harvey.]

FAMILY II. HELMINTHOCLADIACEÆ.

The plants consist of a filamentous thallus, simple or branched, with the secondary axes often arranged in whorls. The main filament may consist of a single row of cells or of an axile row surrounded by cortical rows of smaller cells.

The terminal cells of the gonimoblasts, which are short tufts of filaments, generally form the carpospores. When the carpospore has become detached, the supporting cell grows through the old cell wall and produces a new spore-forming cell. The cystocarp has no definite wall.

Key to Genera.

1. With clustered tufts of branches.... *Batrachospermum**
   Without clustered tufts.......................... 2
2. Thallus three to seven mm. in length........ *Chantransia*
   Thallus thirty to sixty cm. in length............ *Thorea*

Description of Genera.

Batrachospermum Roth.— A wholly fresh-water genus. The plants are diœcious, of a violet or bluish green color. Thallus is from sixteen to twenty cm. in length, moniliform, gelatinous, slippery, consisting of an axile series of cells growing by means of a hemispherical apical cell, and an accessory parallel series, covered with clustered tufts of branches which are more or less scattered. The carpogonium grows in a cell at the extremity of a short branch which stands out directly from the main branch; it possesses a short, straight trichogyne, and after fertilization develops a dense mass of exposed carpospores.

B. vagum (Roth) Ag., Fig. 278.

[*B. anatinum* Sirdt.; *B. Boryanum* Sirdt.; *B. Corbula* Sirdt.; *B. ectocarpum* Sirdt.; *B. moniliforme* var. *typicum*, and var. *chlorosum* Sirdt.; *B. pyramidale* Sirdt.; *B. virgatum* Sirdt.]

Chantransia Fries.— Diœcious, red, steel-blue, or purplish violet, growing in fresh and salt water. Filaments articulate, branched; branches simple or compound; mucilage lacking.

The carpogonium develops, after fertilization, numerous gonimoblasts in small clusters, upwards and on one side. Asexual multiplication by *tetraspores* developed on ends of cells.

Thorea Bory.— This genus possesses but one species, *T. ramosissima* Bory. The thallus is round, filamentous, much branched, the thickness of a horse hair, of a purple-brown or dark brown color, very mucous, and reaching the length of thirty to sixty cm. The branches are short and compact, slightly attenuated, and the cells are from two to five times longer than their diameter. The cells possess starch-like granules, and the spores are naked and non-motile.

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Plate I; Figures 1 to 6; All Magnified 1,000 Diameters.

Fig. 1.	*Oscillatoria subtilissima* Kütz. . .	page	19
Fig. 2.	" *æruginco-cærulea* Kütz. .	"	"
Fig. 3.	*Merismopedia glauca* Näg. . .	"	12
Fig. 4.	" *convoluta* Breb. . .	"	"
Fig. 5.	*Oscillatoria limosa* Ag. . . .	"	19
Fig. 6.	" *percursa* Kütz. . .	"	"

PLATE I.

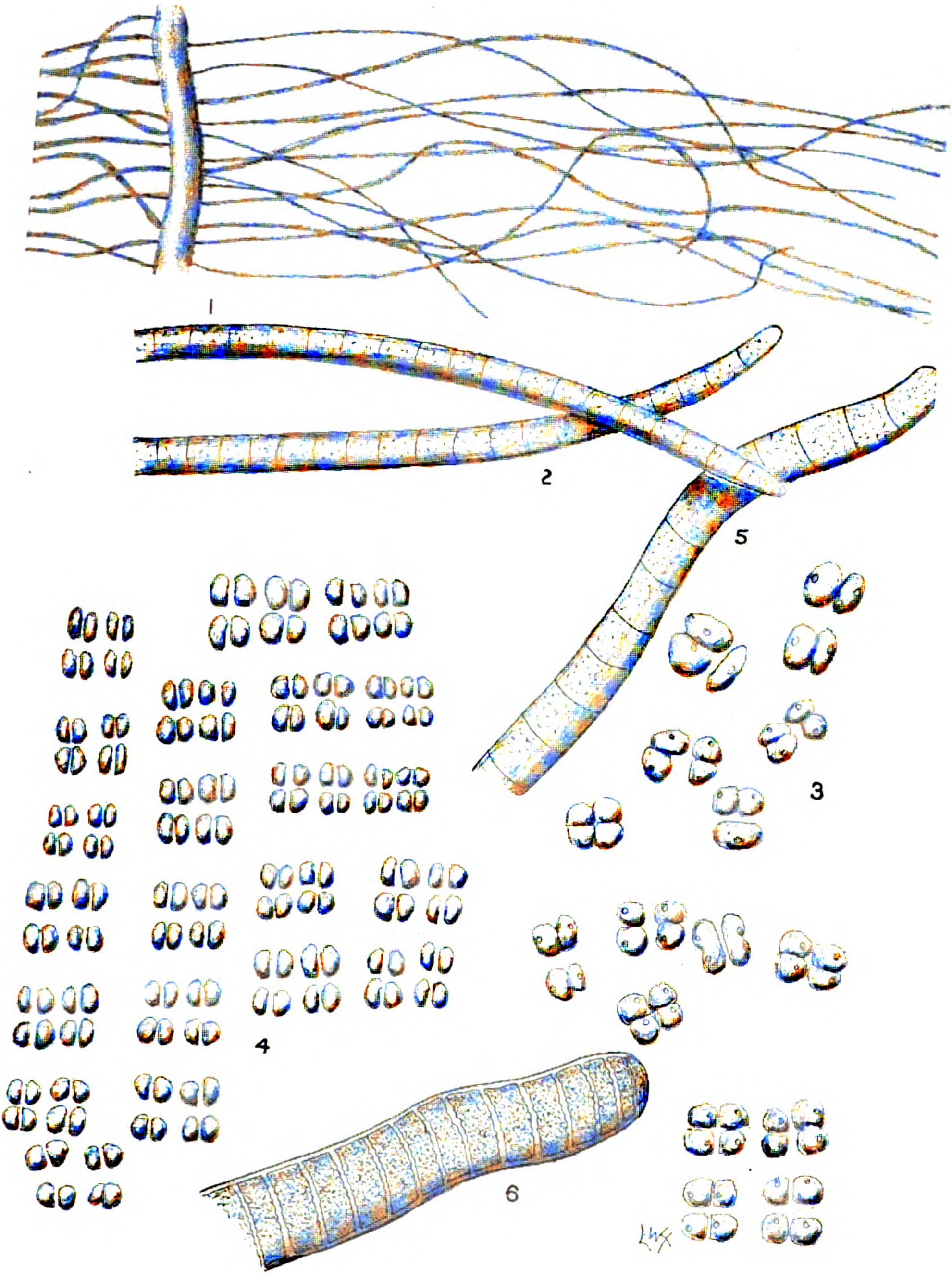


PLATE II; FIGURES 7 TO 10; ALL (EXCEPT FIG. 8*a*) MAGNIFIED 1000 DIAMETERS.

PLATE II.

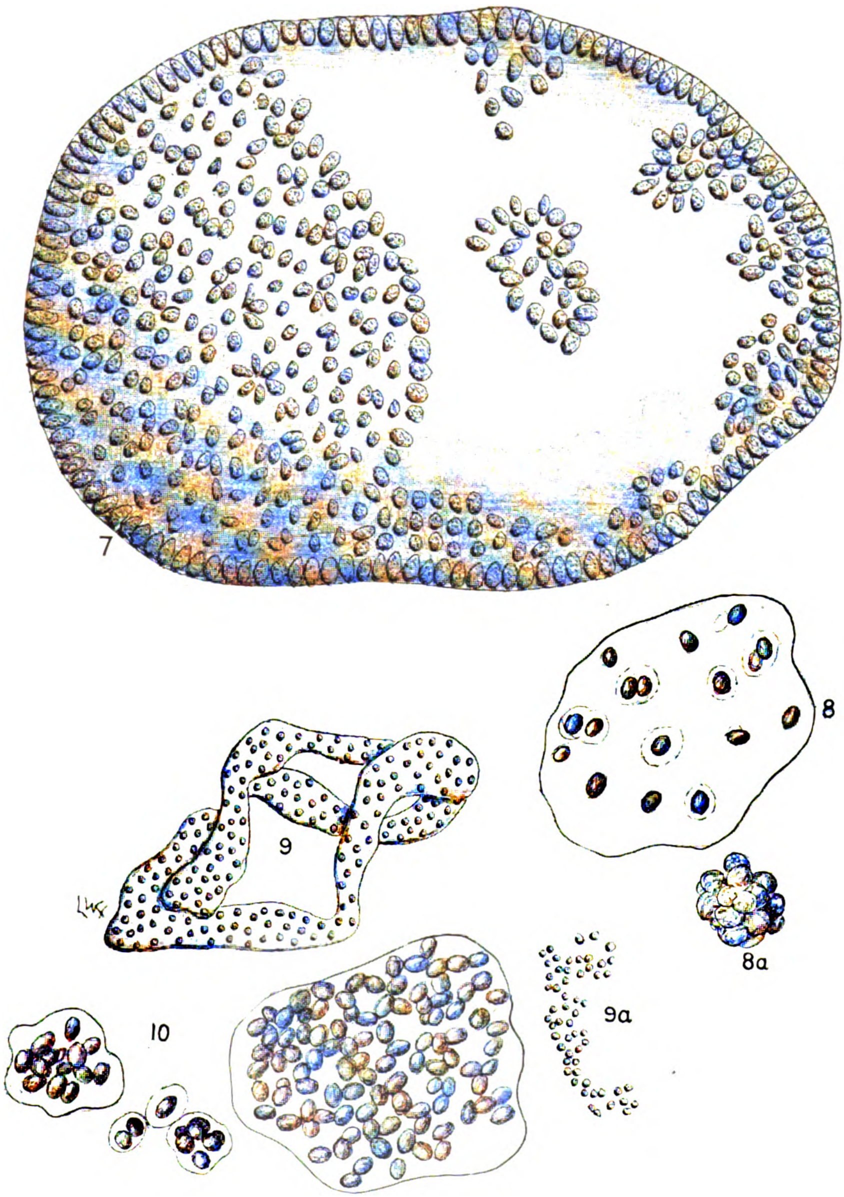


PLATE III; FIGURES 11 TO 15; ALL MAGNIFIED 1000 DIAMETERS.

PLATE III.

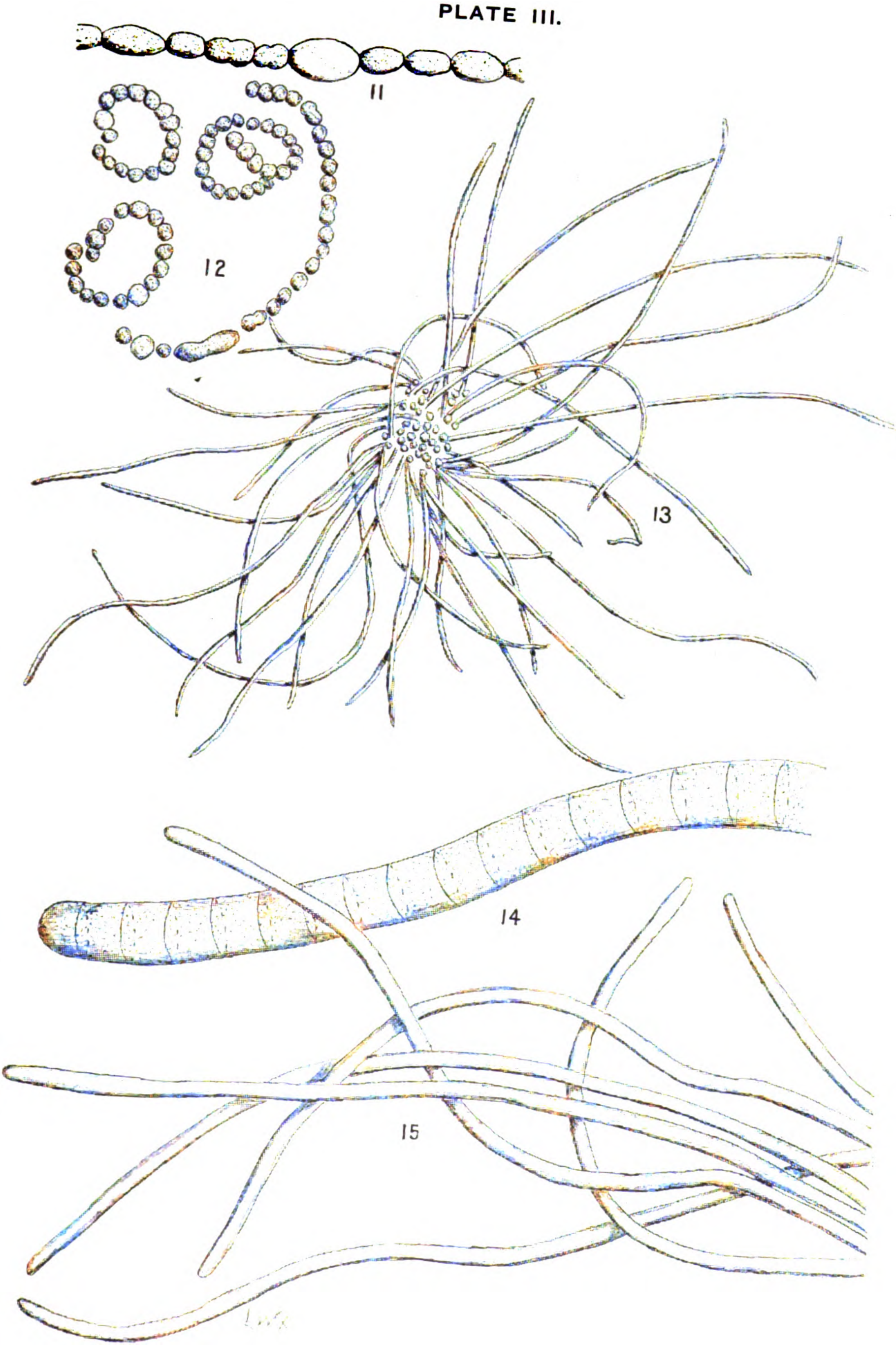


Plate IV; Figures 16 to 19; Fig. 18 Magnified 500 Diameters; the others 1000 Diameters.

Fig. 16.	*Nostoc rupestre* Kütz. . . .	page	21
Fig. 17.	" " " . . .	"	"
Fig. 18.	" sp. (?)	"	"
Fig. 19.	" *comminutum* Kütz. . .	"	"

PLATE IV.

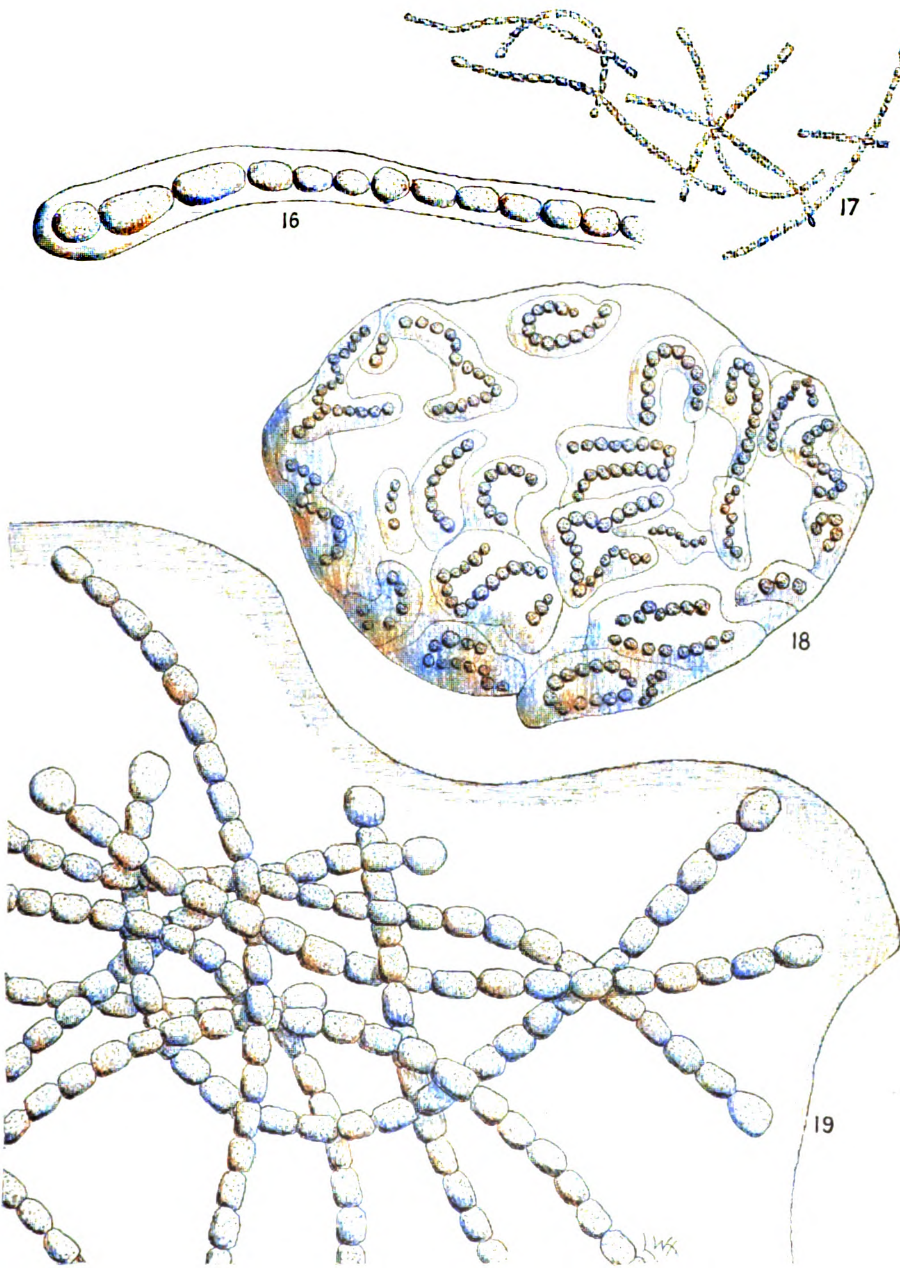


PLATE V; FIGURES 20 TO 29; FIGS. 26 AND 29 MAGNIFIED 500 DIAMETERS; ALL OTHERS 1000 DIAMETERS.

PLATE V.

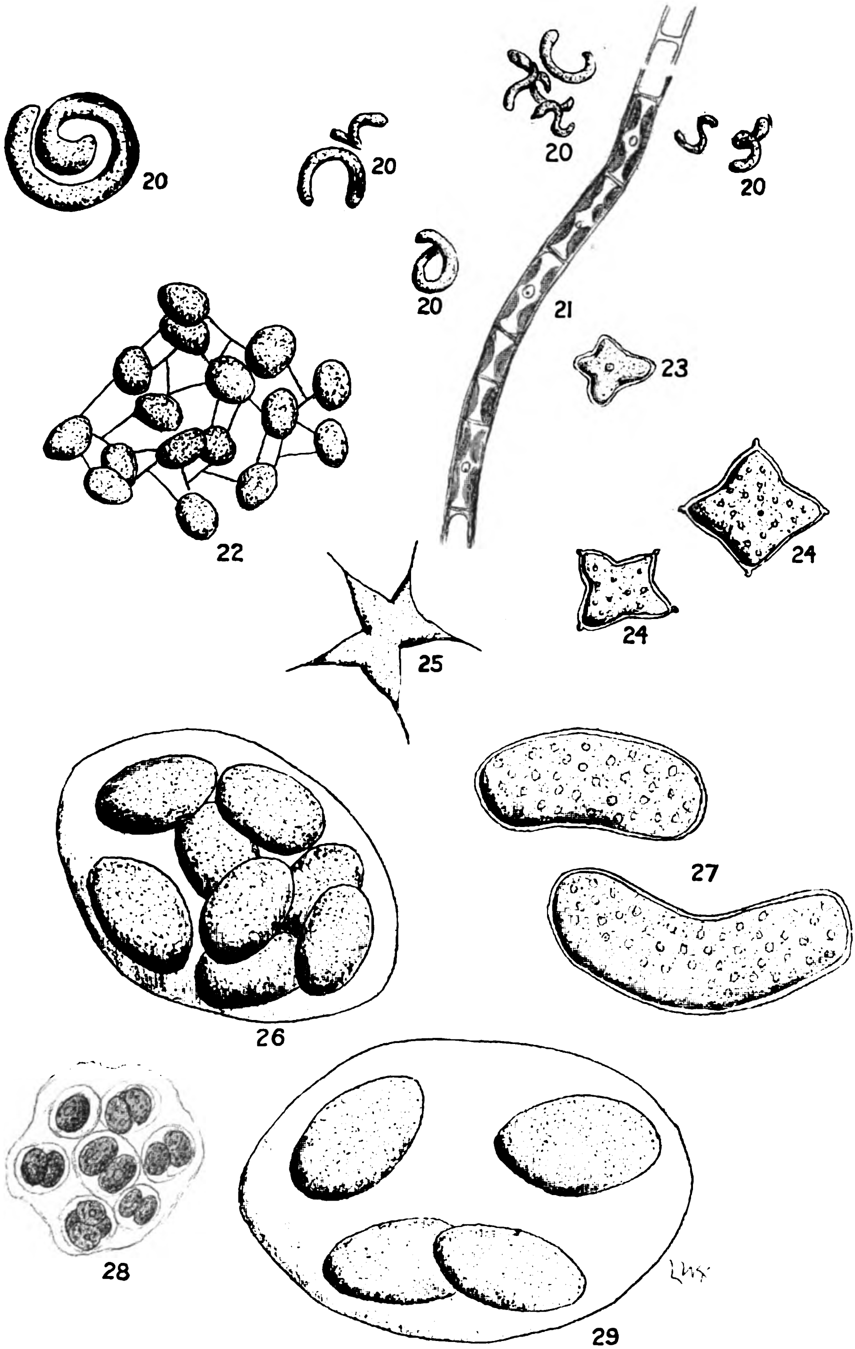


PLATE VI; FIGURES 30 TO 49; ALL MAGNIFIED 1000 DIAMETERS.

PLATE VI.

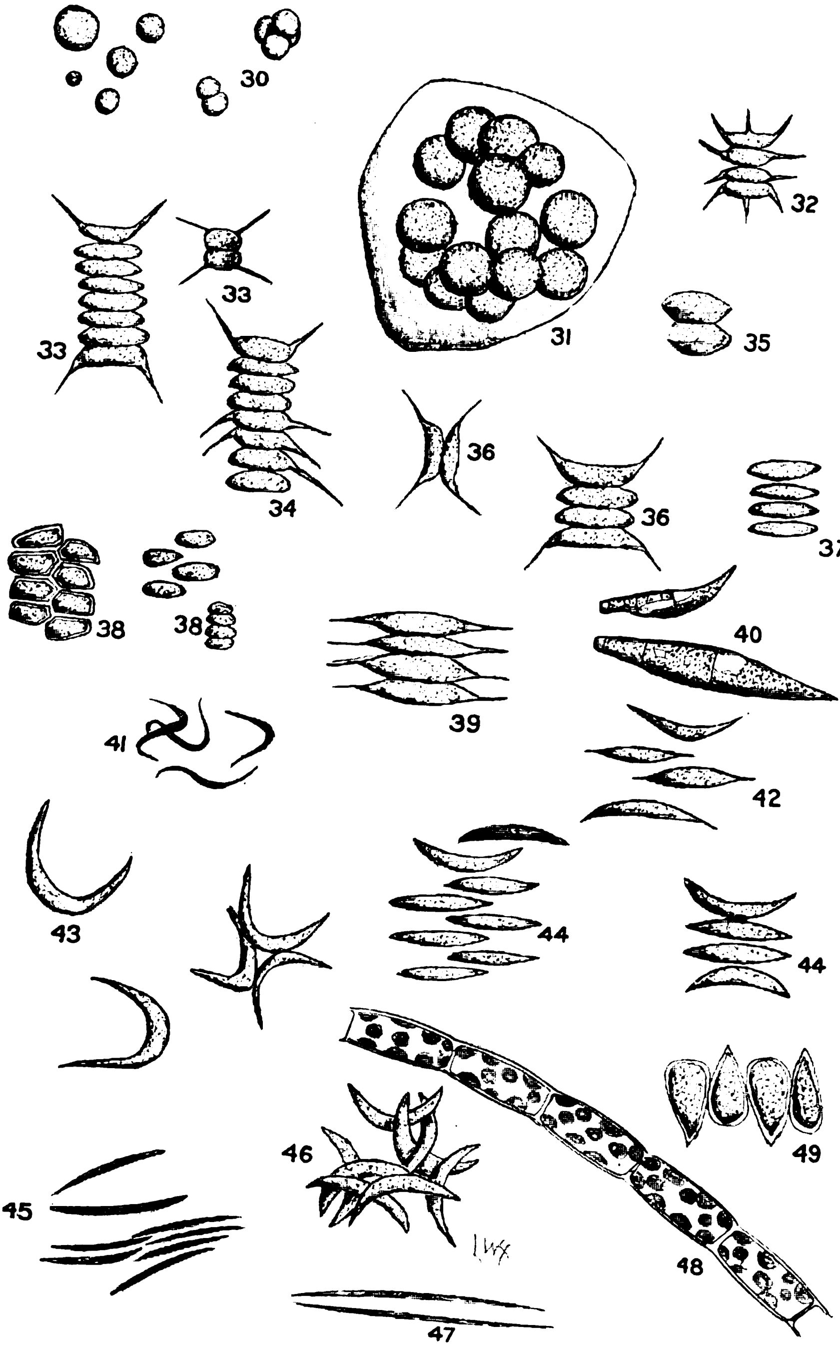


Plate VII; Figures 50 to 56; All except Fig. 54*a* Magnified 1000 Diameters.

PLATE VII.

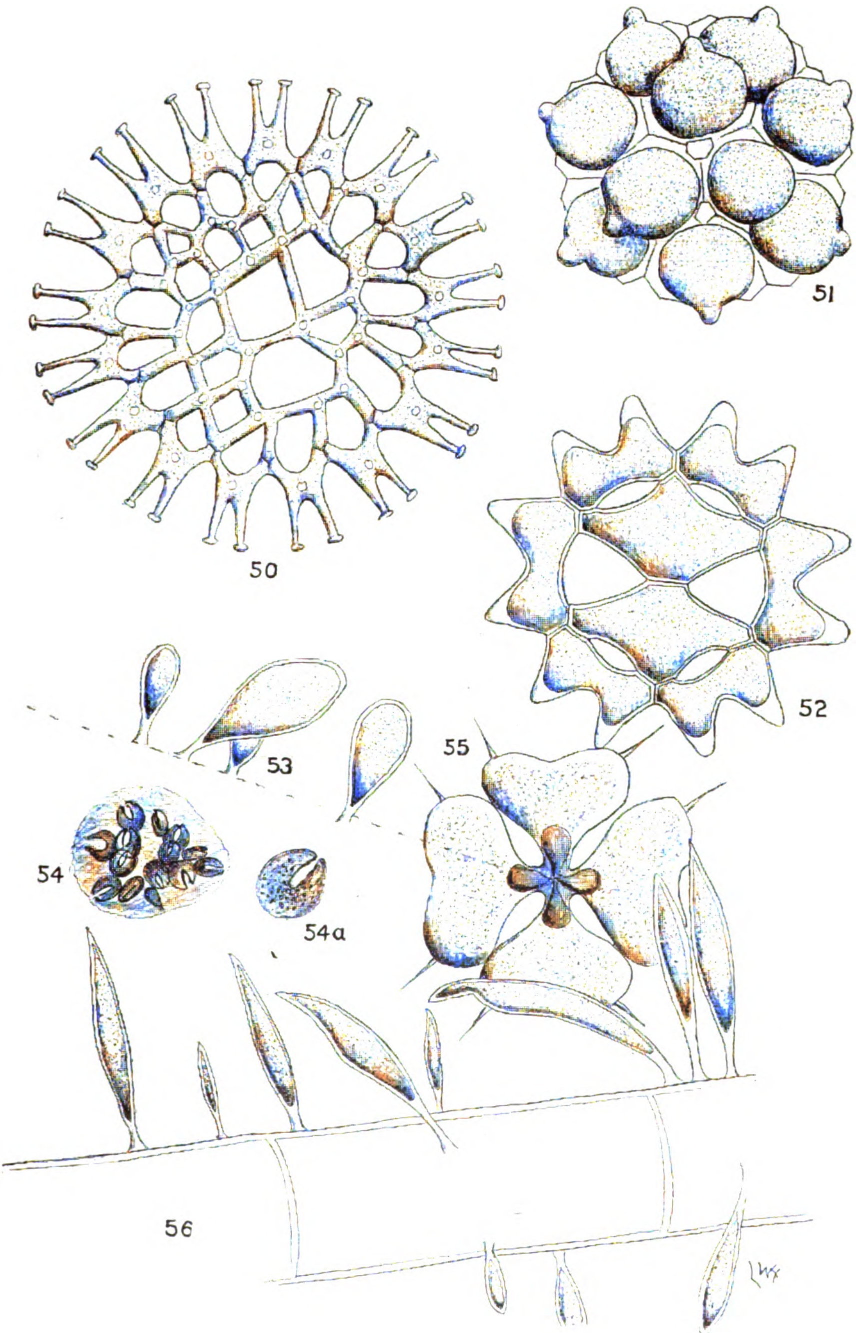
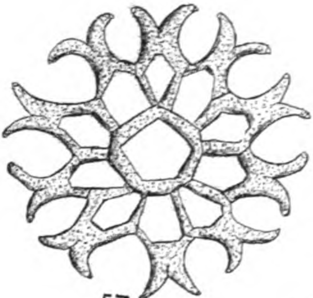


PLATE VIII; FIGURES 57 TO 60; ALL MAGNIFIED 500 DIAMETERS.

PLATE VIII.



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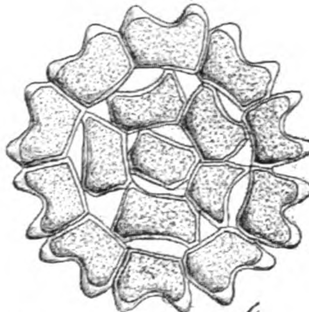

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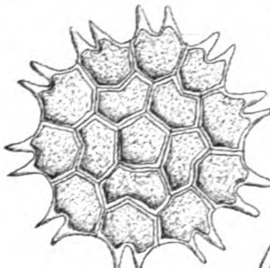

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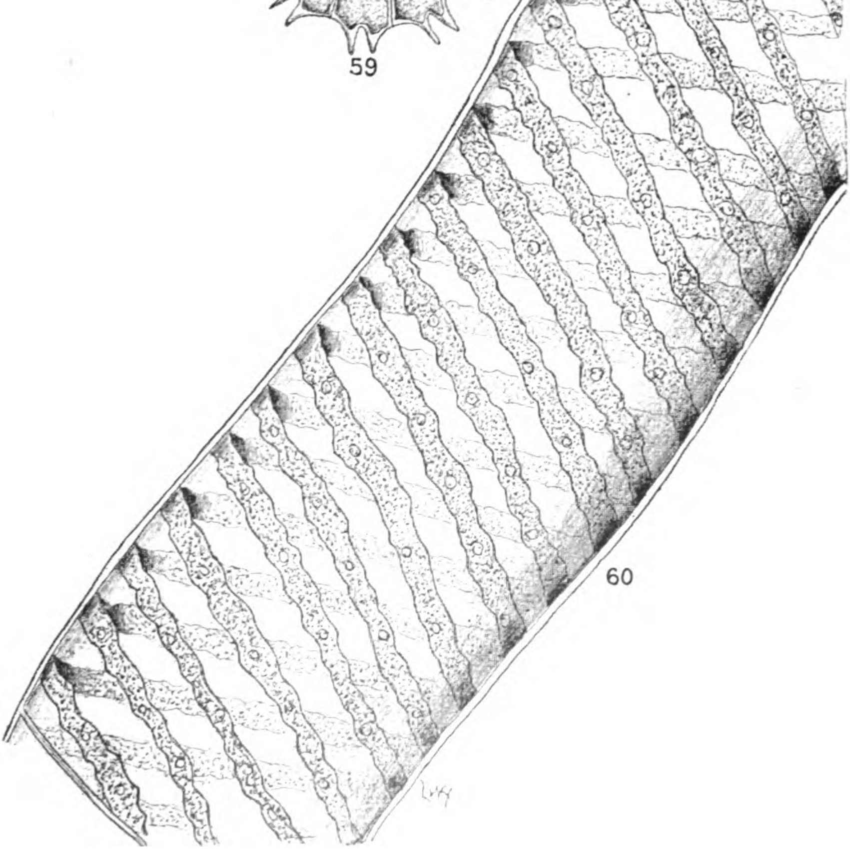

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PLATE IX; FIGURES 61 TO 71; FIG. 68 MAGNIFIED 500 DIAMETERS; ALL OTHERS 1000 DIAMETERS.

PLATE IX.

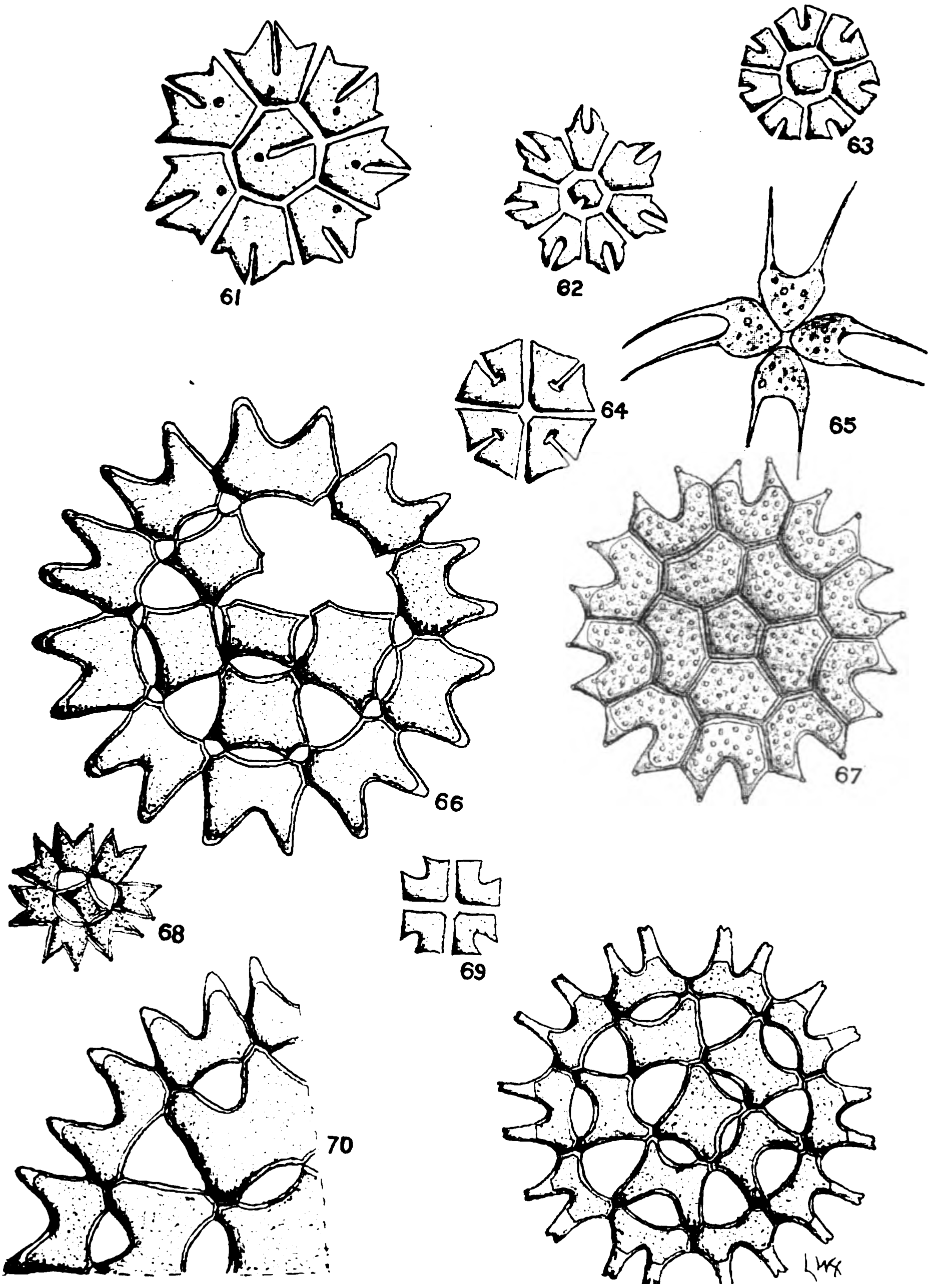

PLATE VI; FIGURES 30 TO 49; ALL MAGNIFIED 1000 DIAMETERS.

PLATE VI.

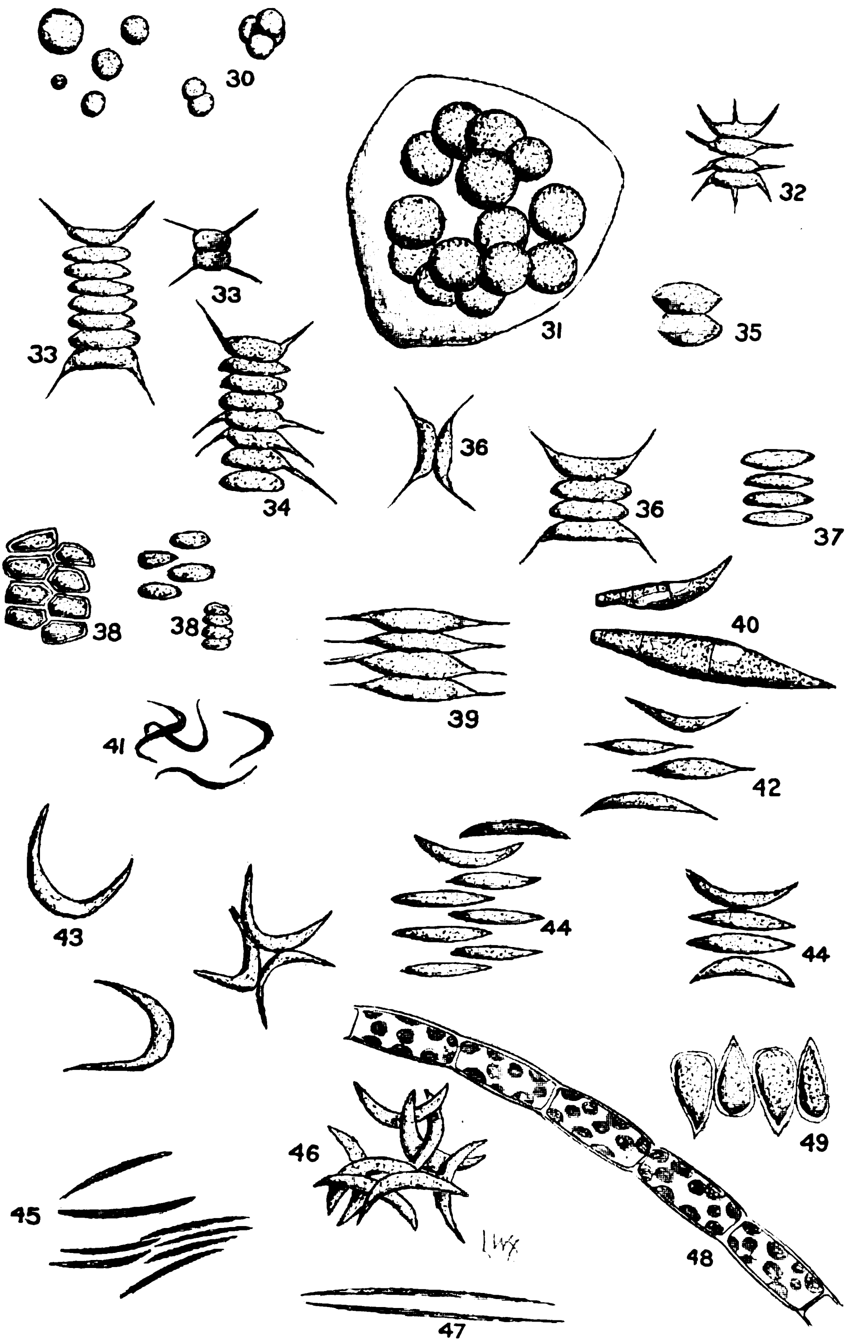
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PLATE VII; FIGURES 50 TO 56; ALL EXCEPT FIG. 54*a* MAGNIFIED 1000 DIAMETERS.

PLATE VII.

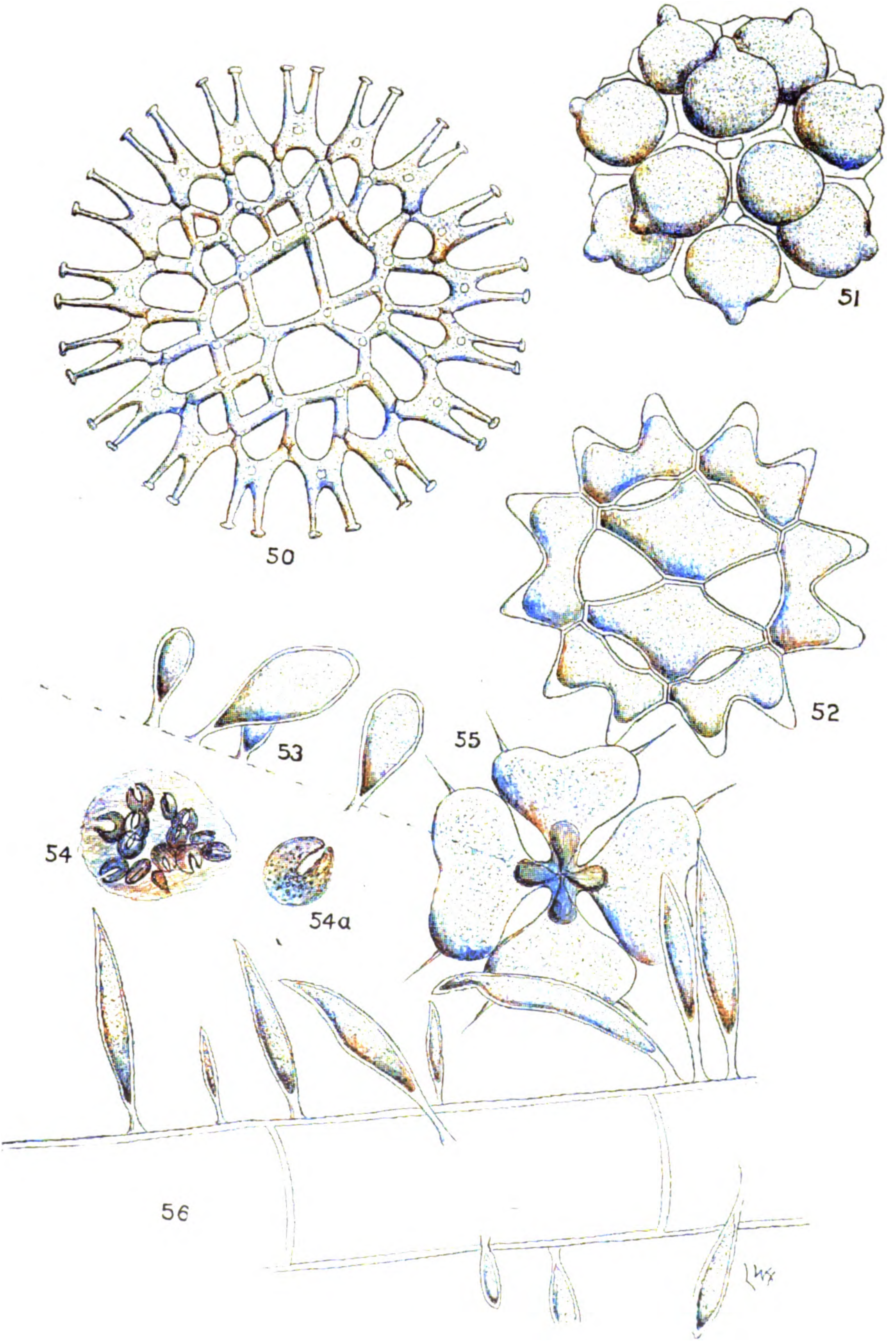
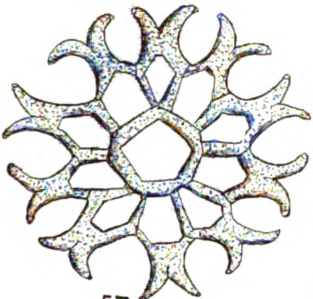


PLATE VIII; FIGURES 57 TO 60; ALL MAGNIFIED 500 DIAMETERS.

PLATE VIII.



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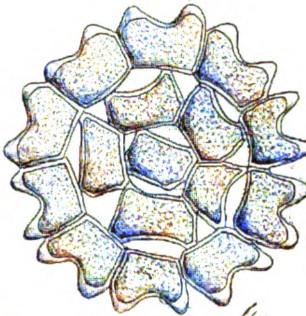

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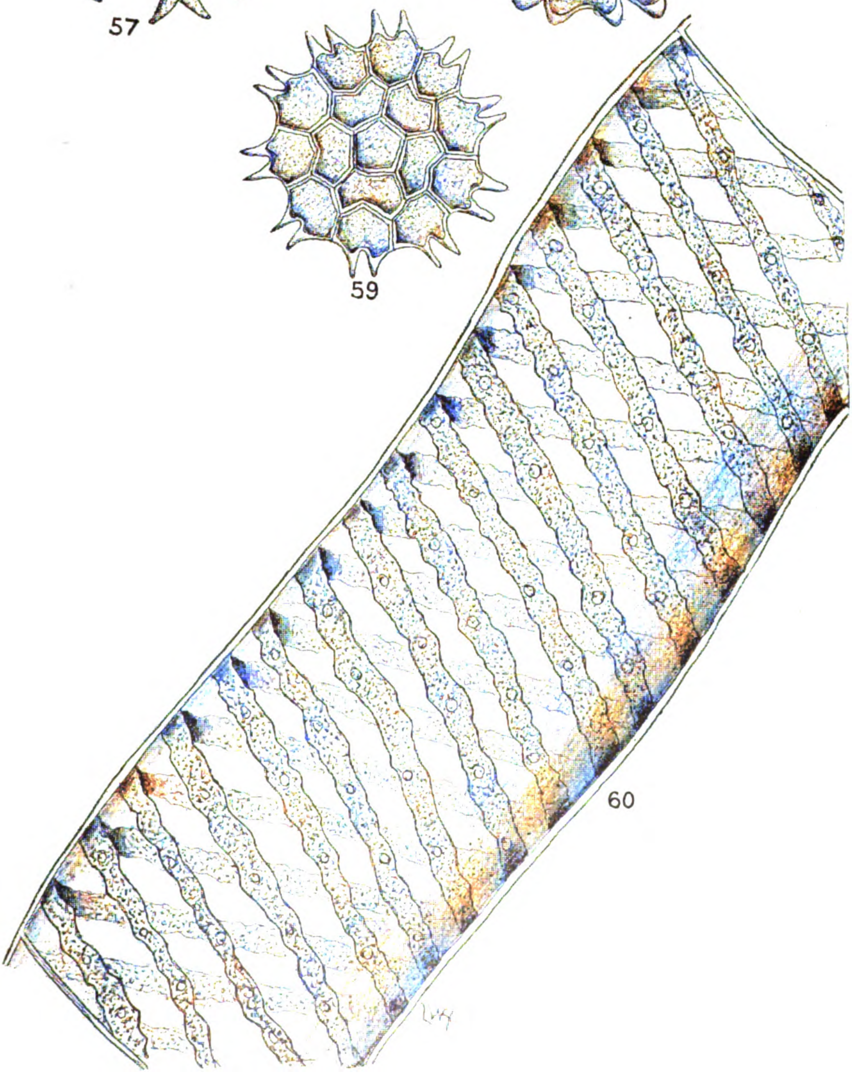

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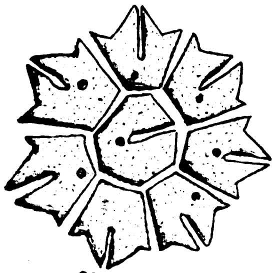
Plate IX; Figures 61 to 71; Fig. 68 Magnified 500 Diameters; all others 1000 Diameters.

Figs. 61-63.	*Pediastrum Ehrenbergii* A. Br. .	page	38
Fig. 64.	" " var. *truncatum* Braun	"	"
Fig. 65.	*Pediastrum* sp. (?)	"	"
Fig. 66.	" *pertusum* Kütz. . .	"	"
Fig. 67.	" *Boryanum* (Turp.) Meneg. var. *granulatum* Kütz. . .	"	"
Fig. 68.	*Pediastrum pertusum* Kütz. . .	"	"
Fig. 69.	" *tetras* Ehrb. . . .	"	"
Figs. 70, 71.	" *pertusum* Kütz. . .	"	"

PLATE IX.



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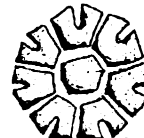

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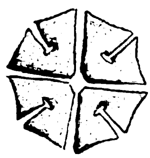

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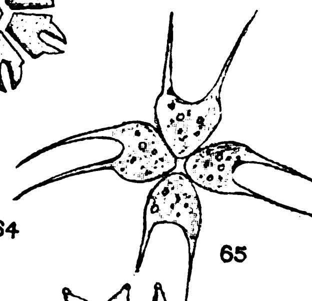

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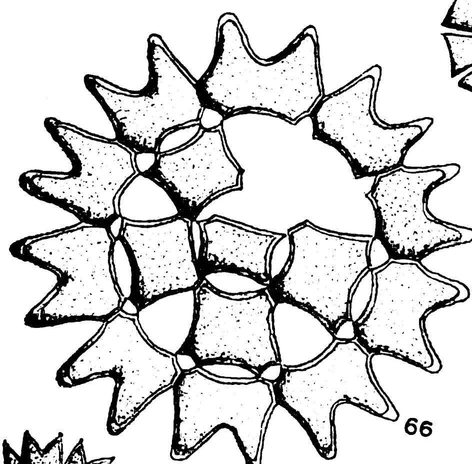

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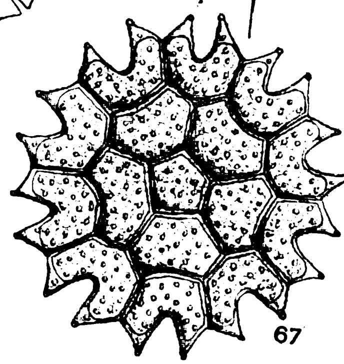

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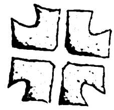

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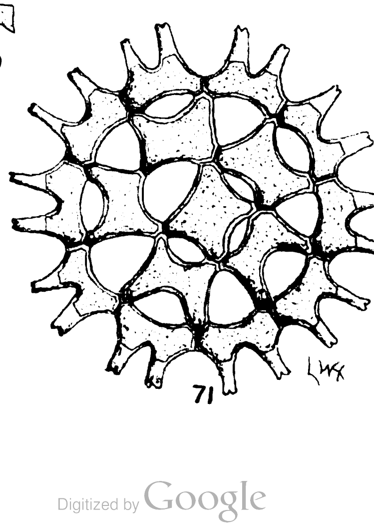


71

PLATE X; FIGURES 72 TO 77.

PLATE X.

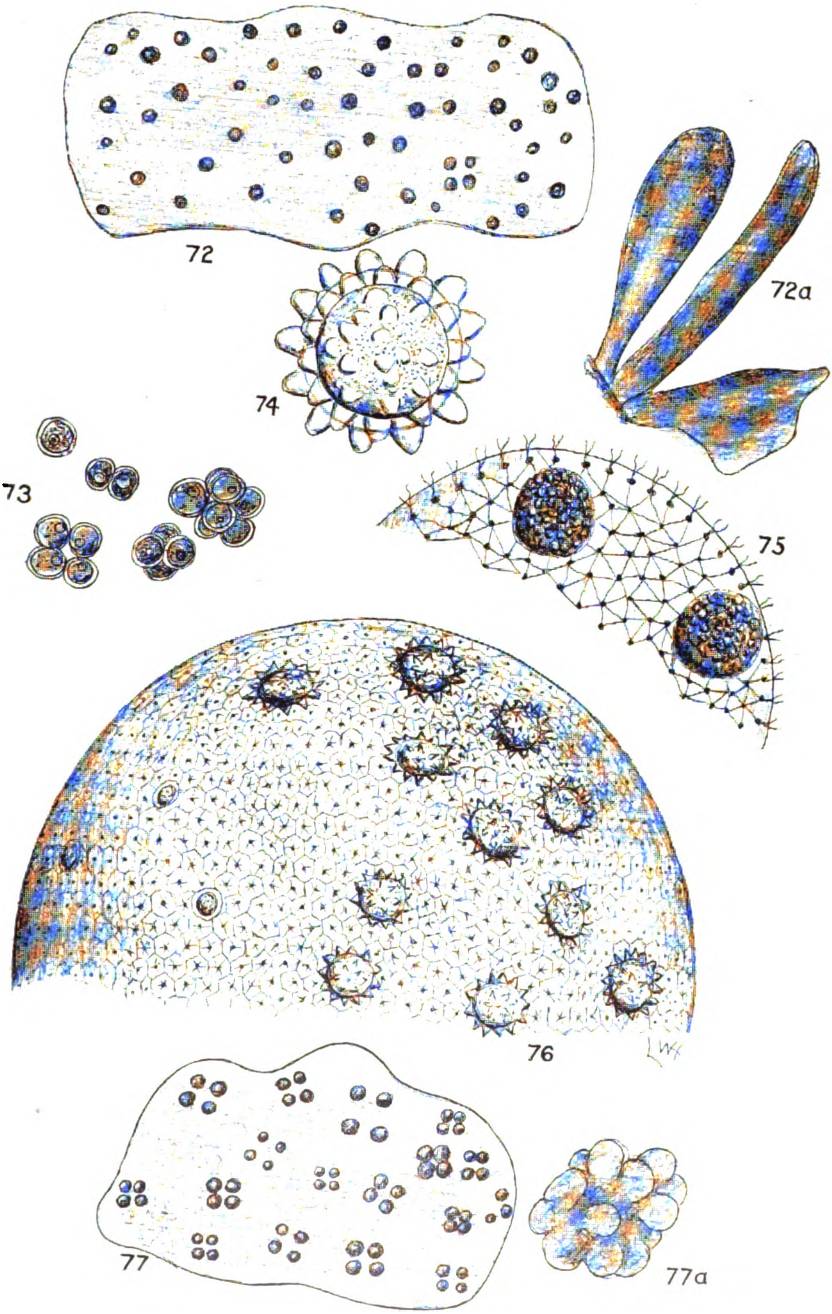


PLATE XI; FIGURES 78, 79; MAGNIFIED 250 DIAMETERS.

PLATE XI.

PLATE XII; FIGURES 80 TO 82.

Fig. 80*a*.	*Coleochæte irregularis* Pringsh. (?) (250 diameters)	page	51
b.	*Herposteiron Confervicola* Näg. .	"	50
c.	Diatom		
Fig. 81.	*Myxonema lubricum* var. *varians* Haz. (500 diameters)	"	47
Fig. 82.	*Myxonema tenue* (Ag.) Rab. (250 diameters)	"	"

PLATE XII.

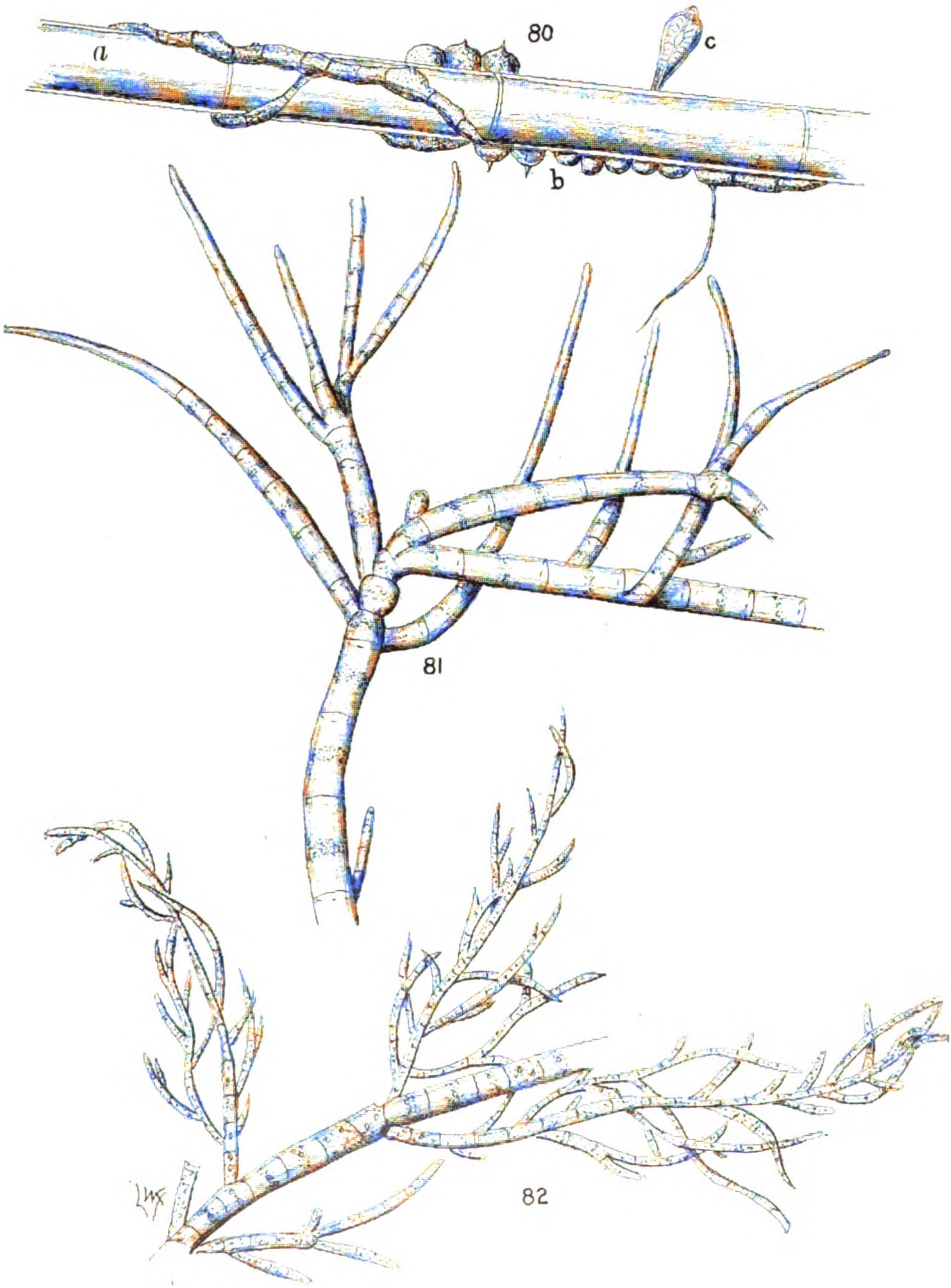
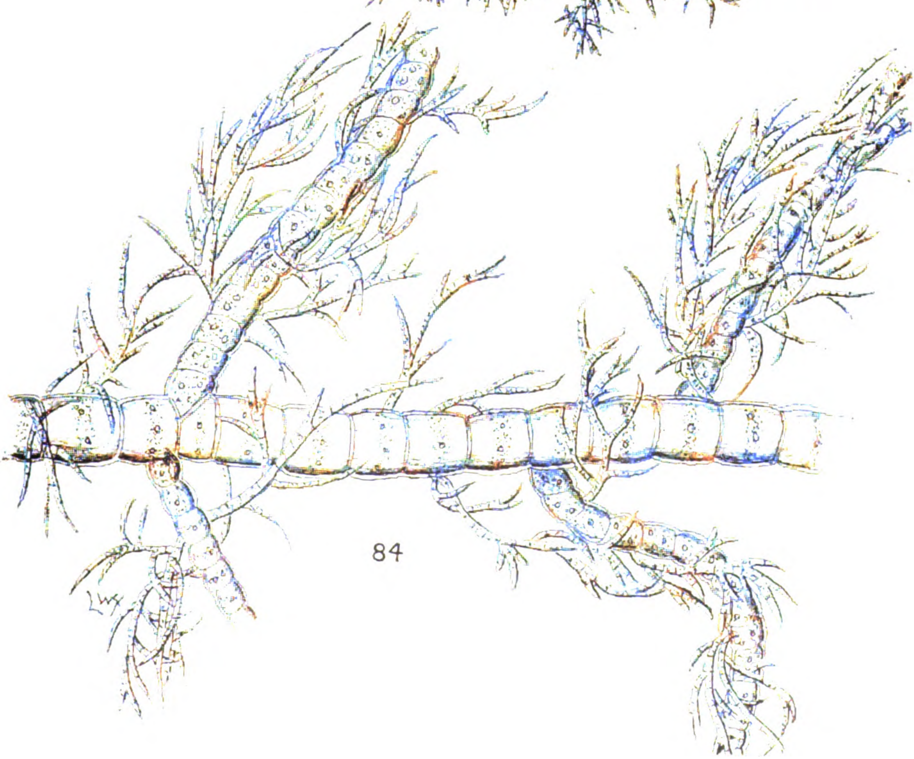


PLATE XIII; FIGURES 83, 84; MAGNIFIED 100 DIAMETERS.

PLATE XIII.

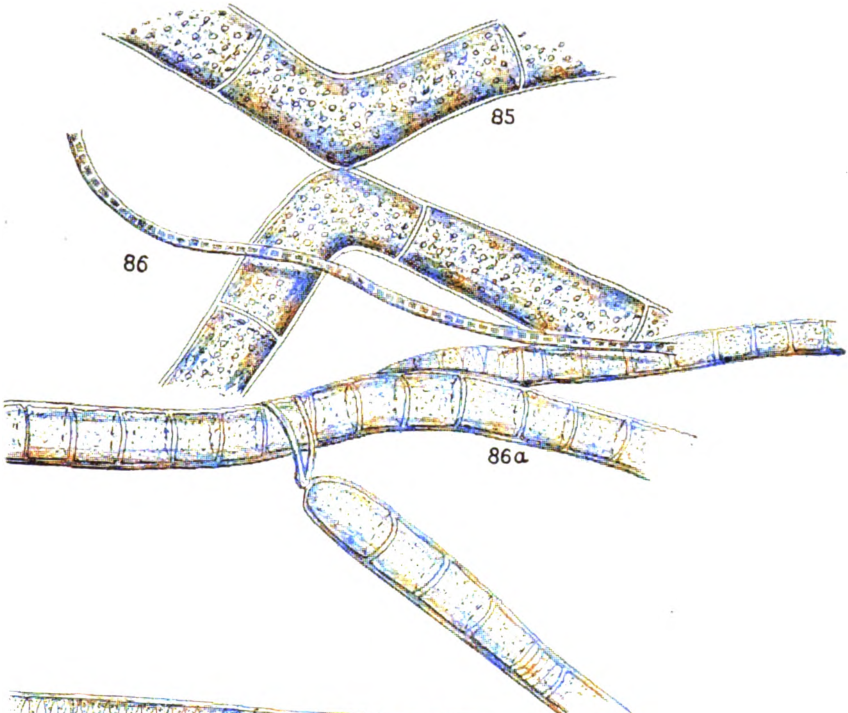
83



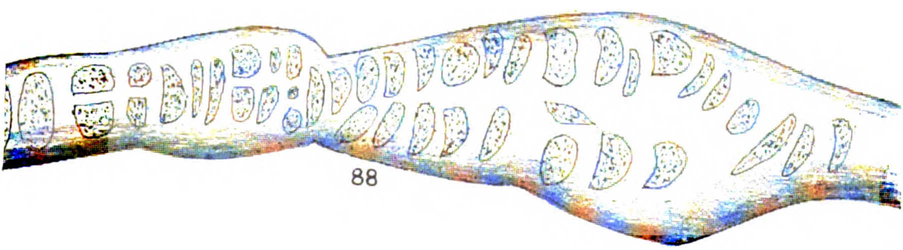
84

PLATE XIV; FIGURES 85 TO 89.

PLATE XIV.



87



88

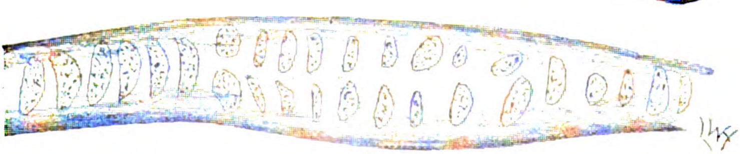


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Plate XV; Figures 90 to 95; Magnified 1000 Diameters, except Fig. 91.

Fig. 90.	*Ulothrix*. Young stage . . .	page	49
Fig. 91.	" " " (low power)	"	"
Fig. 92.	*Microspora Stagnorum* (Kütz.) Lag.	"	50
Fig. 93.	*Ulothrix tenerrima* Kütz. . .	"	49
Fig. 94.	" *zonata* (Web. and Mohr) Kütz.	"	"
Fig. 95.	*Ulothrix* sp. (?)	"	"

PLATE XV.

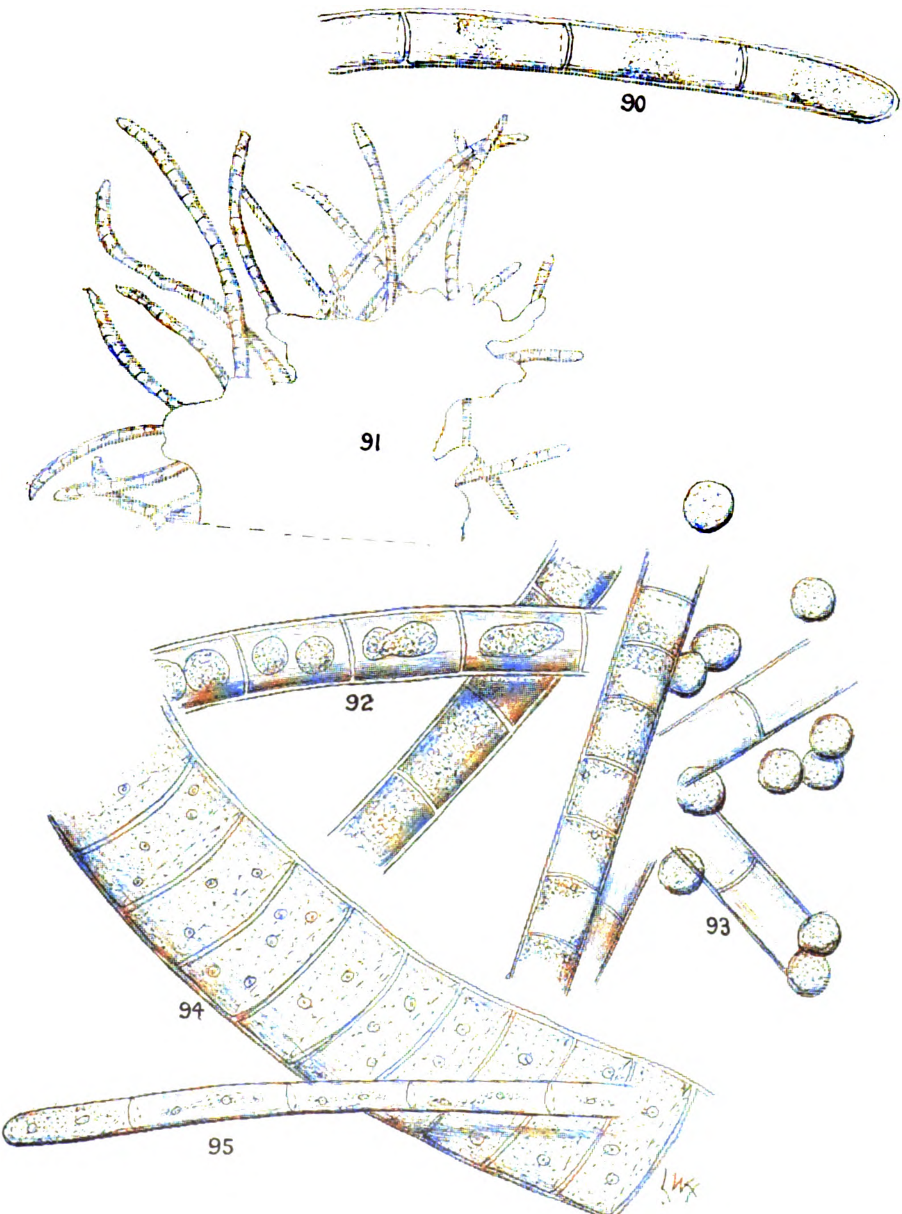


PLATE XVI; FIGURES 96 TO 98; MAGNIFIED 1000 DIAMETERS.

Fig. 96.	*Œdogonium* sp. (?)	page	52
Fig. 97.	*Bulbochæte* sp. (?)	"	"
Fig. 98.	" " Young stage . .	"	"

PLATE XVI.

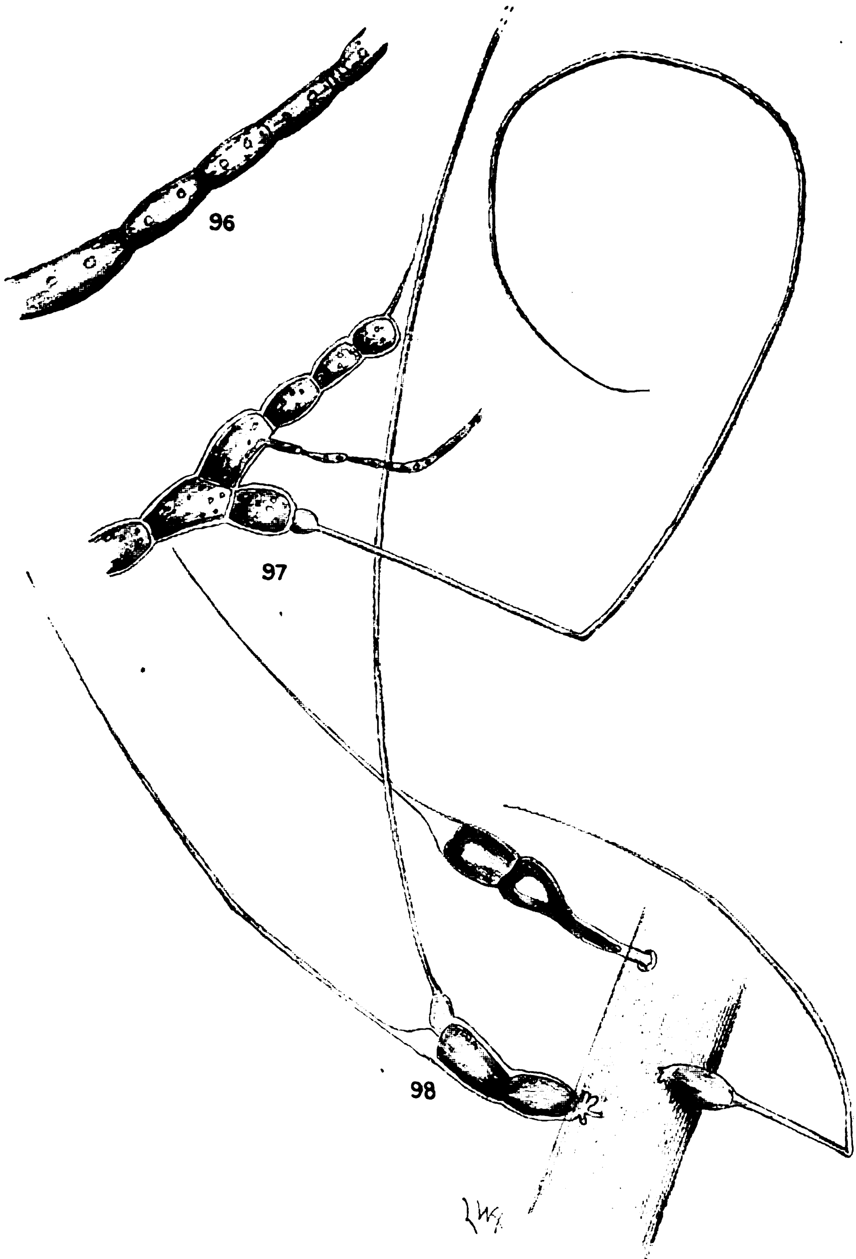


Plate XVII; Figures 99 to 105; Magnified 1000 Diameters.

Fig. 99.	*Cosmarium Broomei* Thwaites .	page	64
Fig. 100.	" *tumidum* Lund. . .	"	"
Fig. 100*a*.	" " " (?) .	"	"
Fig. 101.	*Pleurotænium* sp. (?) . . .	"	"
Fig. 102.	*Cosmarium ornatum* Ralfs . .	"	61
Fig. 103.	*Pleurotænium Baculum* Breb. .	"	"
Fig. 104.	*Euastrum verrucosum* (Ehrb.) Ralfs	"	62
Fig. 105.	" *integrum* Wolle . .	"	"

PLATE XVII.

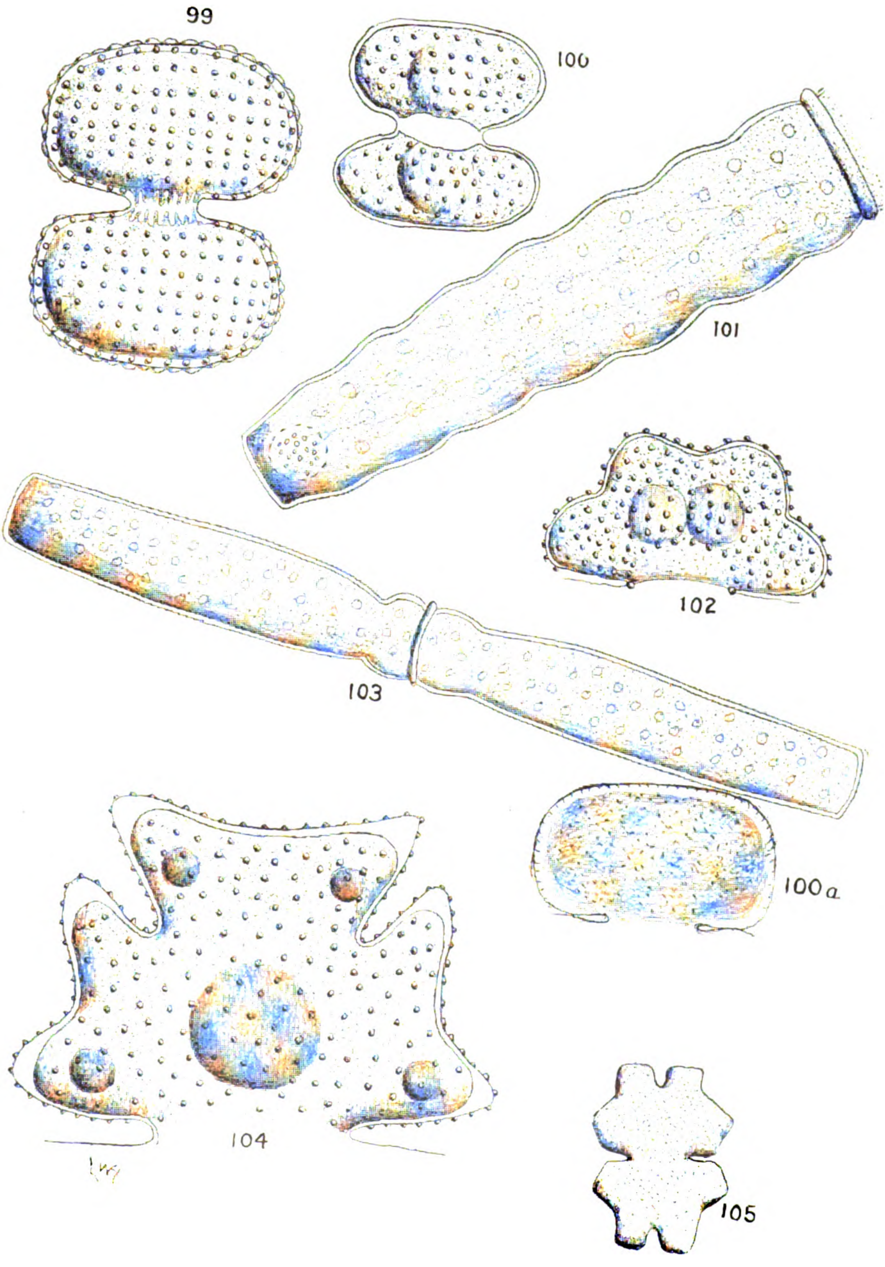
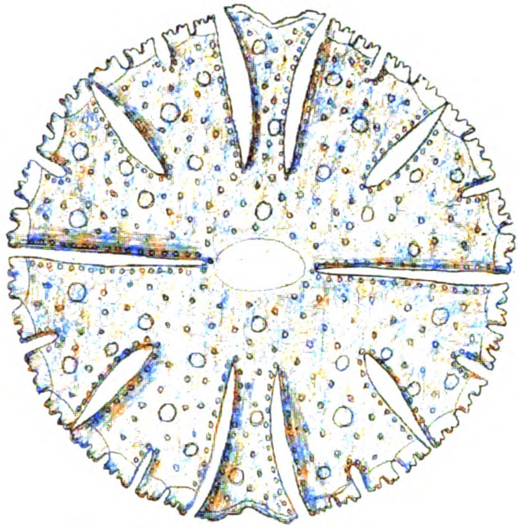


PLATE XVIII; FIGURES 106 TO 108; FIG. 107 MAGNIFIED 1000 DIAMETERS; OTHERS 500 DIAMETERS.

PLATE XVIII.



106

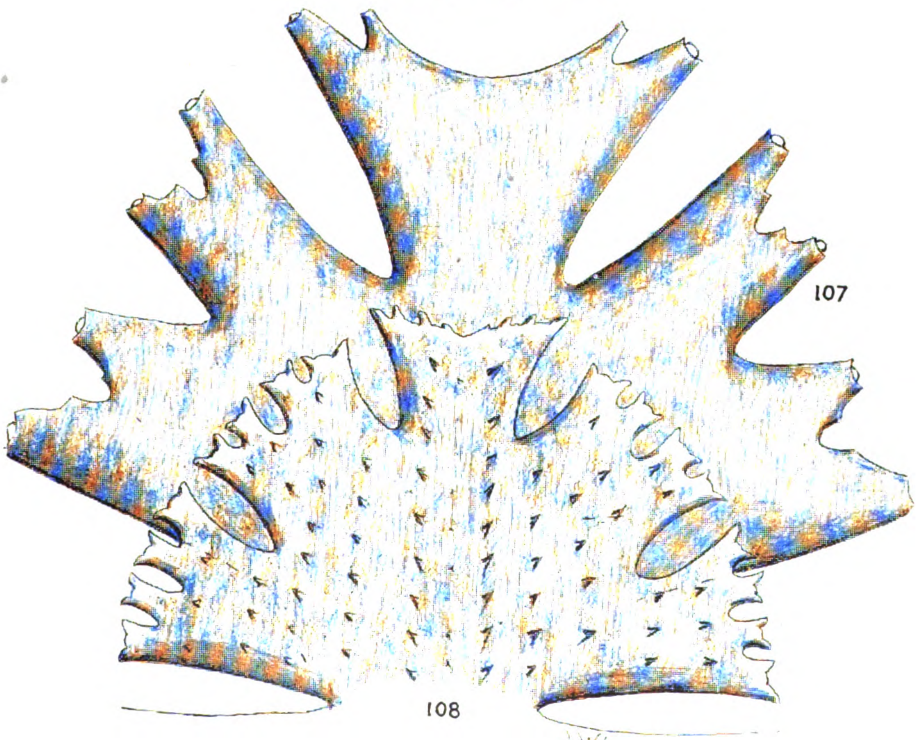


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PLATE XIX; FIGURES 109 TO 121; MAGNIFIED 1000 DIAMETERS.

PLATE XIX.

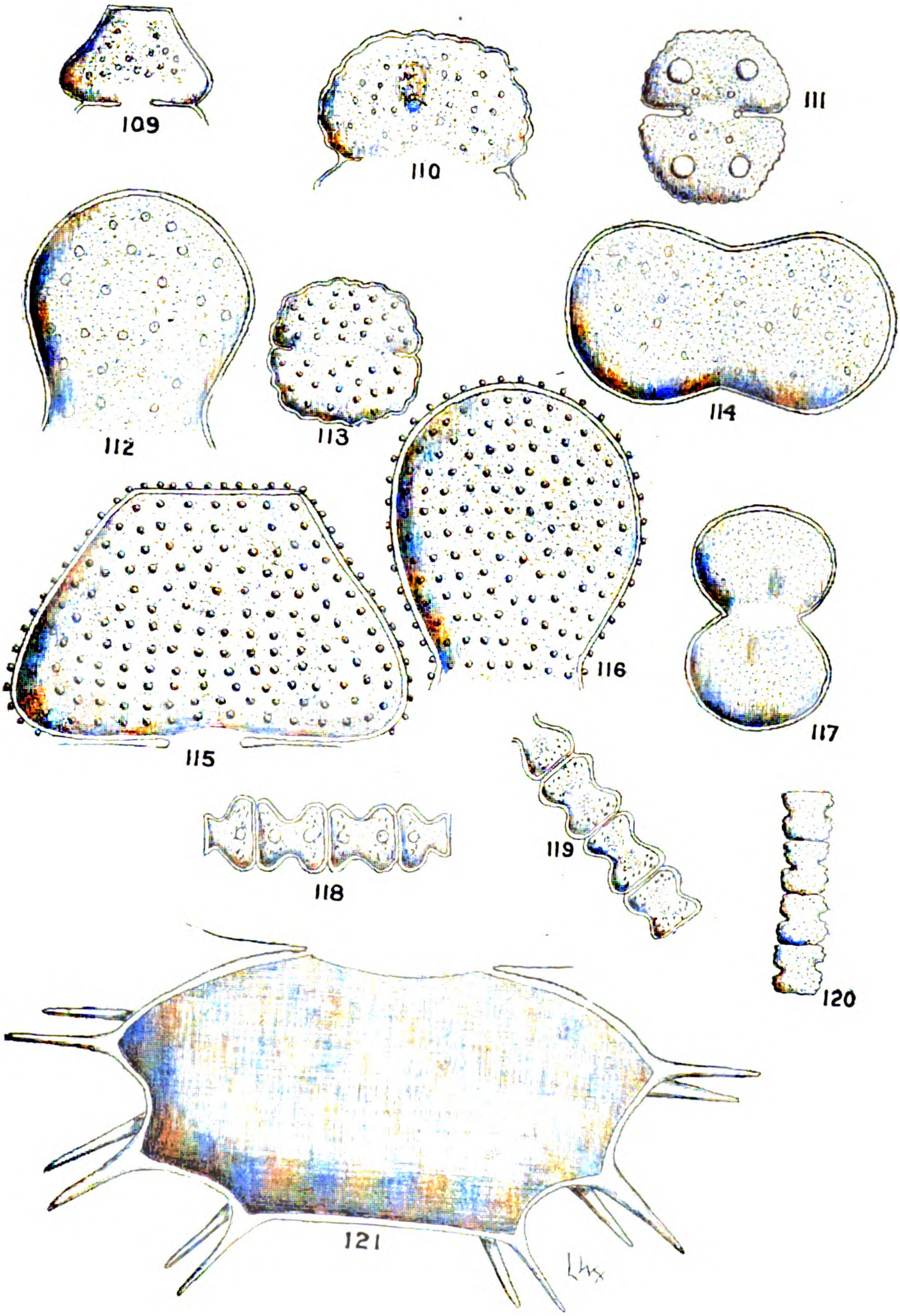


PLATE XX; FIGURES 122 TO 133; MAGNIFIED 1000 DIAMETERS.

Fig. 122. *Staurastrum dejectum* var. *convergens* Wolle	page	62
Figs. 123, 124. *Staurastrum orbiculare* (Ehrb.) Ralfs.	"	"
Fig. 125. *Staurastrum dejectum* var. *mucronatum* Ralfs	"	"
Figs. 126, 127. *Staurastrum megacanthum* Lund.	"	"
Fig. 128. *Staurastrum brevispinum* Breb. .	"	"
Fig. 129. " *muricatum* Breb. .	"	"
Fig. 130. " *crasum* Breb. . .	"	"
Fig. 131. " " " Showing multiplication by division .	"	"
Fig. 132. *Staurastrum odonatum* Wolle . .	"	"
Fig. 133. " *hirsutum* (Ehrb.) Breb.	"	"

PLATE XX.

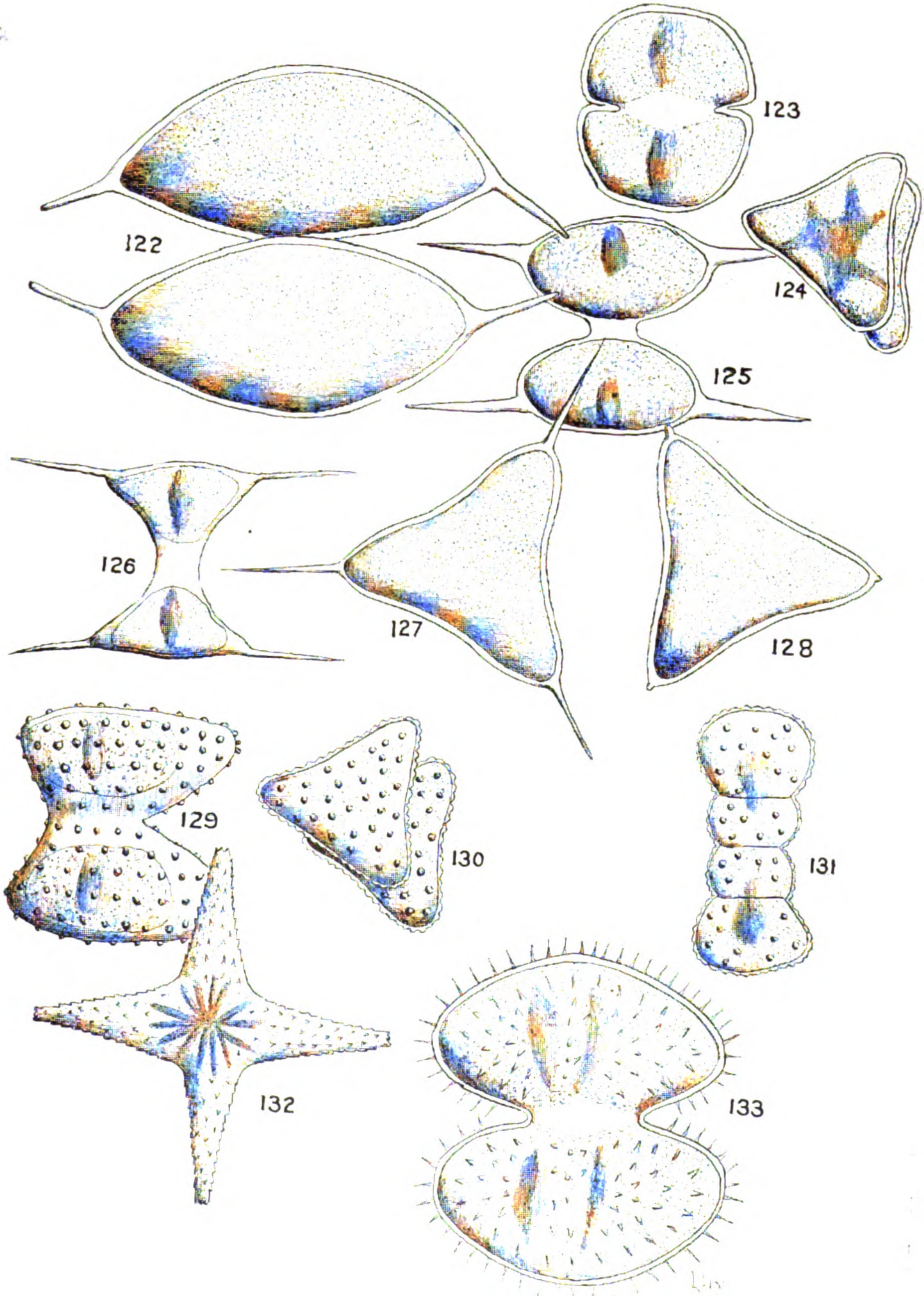


PLATE XXI; FIGURES 134 TO 144; MAGNIFIED 1000 DIAMETERS.

Figs. 134, 135.	*Staurastrum Ravenelii* Wood (?)	page	62
Fig. 136.	*Staurastrum furcigerum* Breb. .	"	"
Figs. 137-142.	*Staurastrum* species undetermined	"	"
Fig. 143.	*Staurastrum iotanum* Wolle . .	"	"
Fig. 144.	" *eustephanum* Ralfs .	"	"

PLATE XXI.

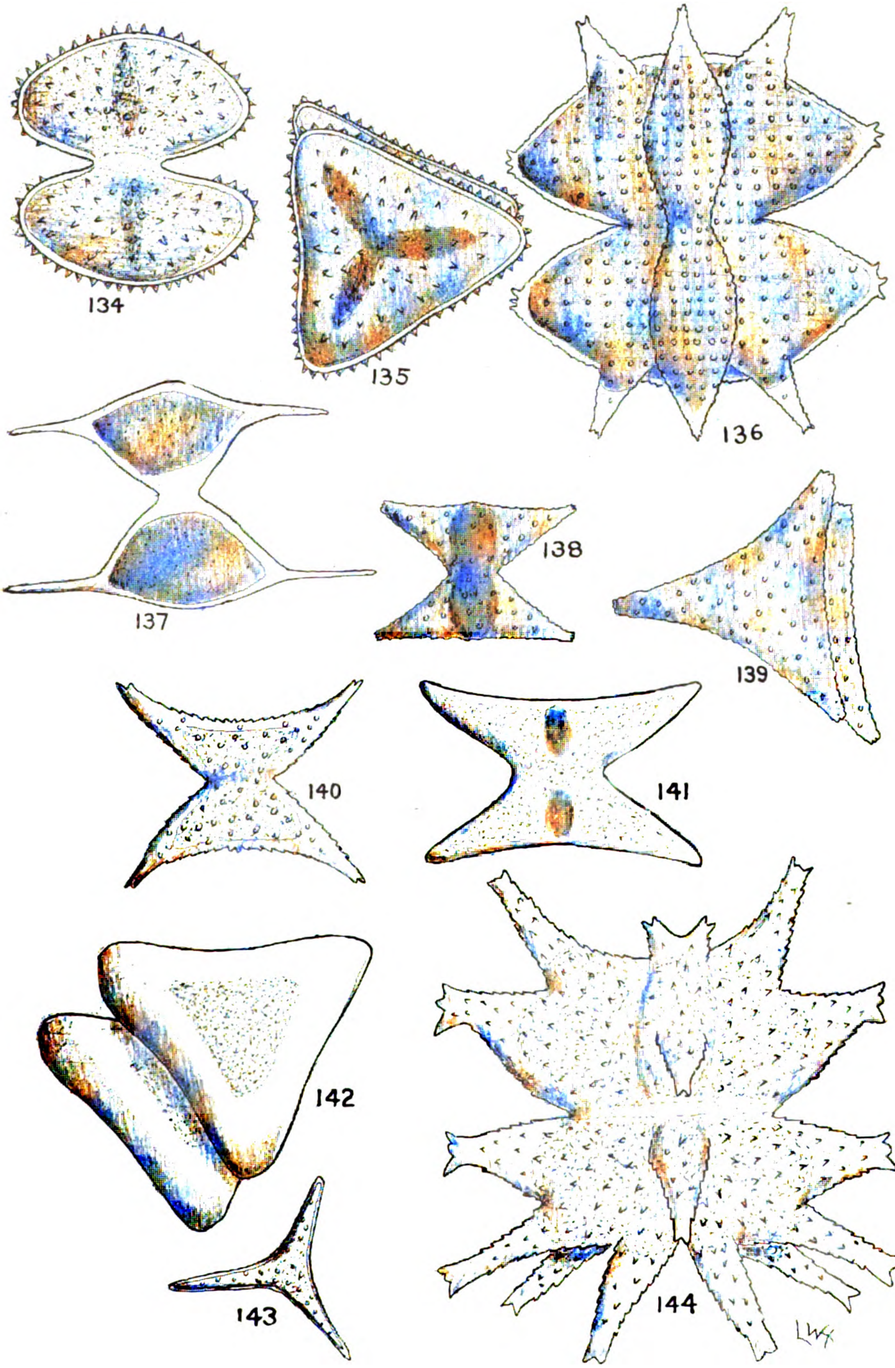


Plate XXII; Figures 145 to 151; Figures 147, 149, 151 Magnified 500 Diameters; Others 1000 Diameters.

PLATE XXII.

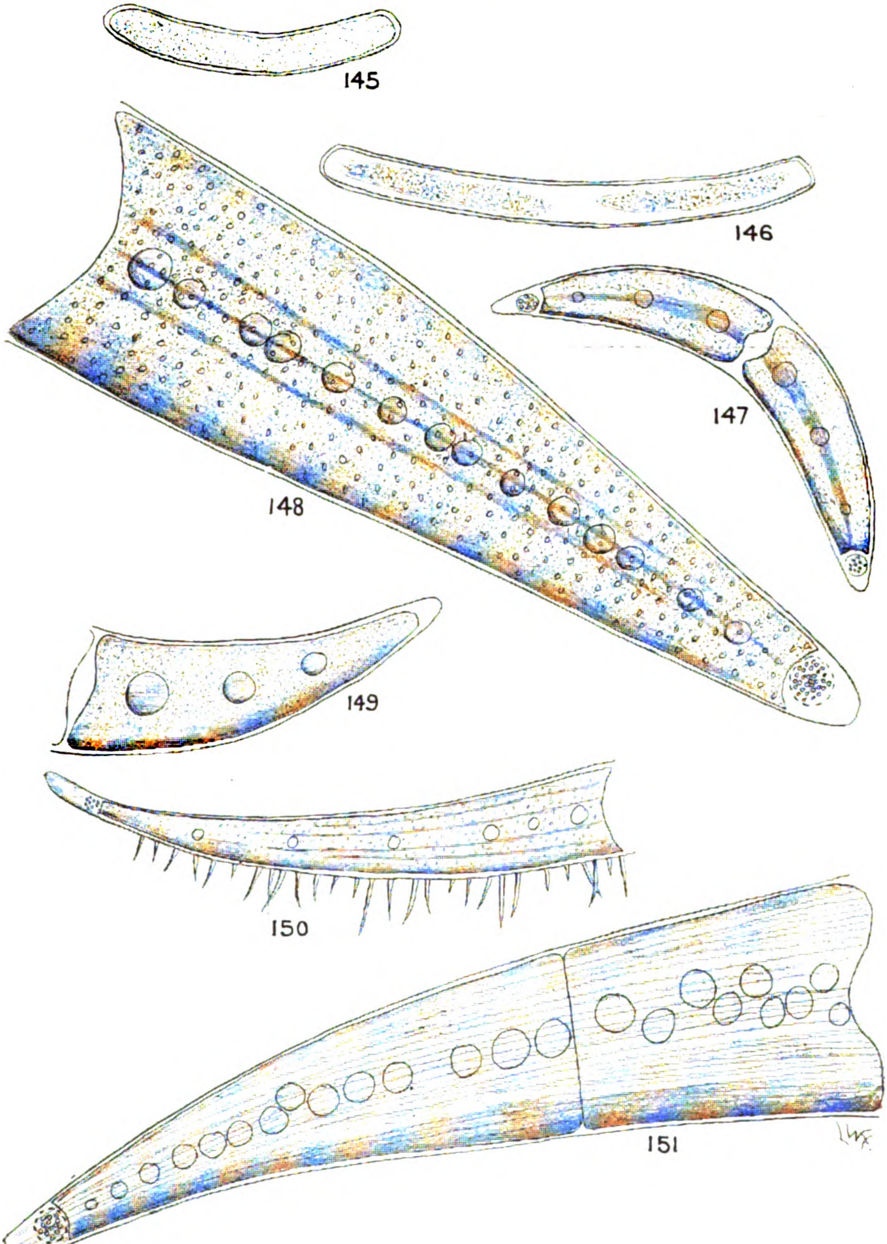


PLATE XXIII; FIGURES 152 TO 159; FIGS. 152, 157, 158 MAGNIFIED 500 DIAMETERS; OTHERS 1000 DIAMETERS.

PLATE XXIII.

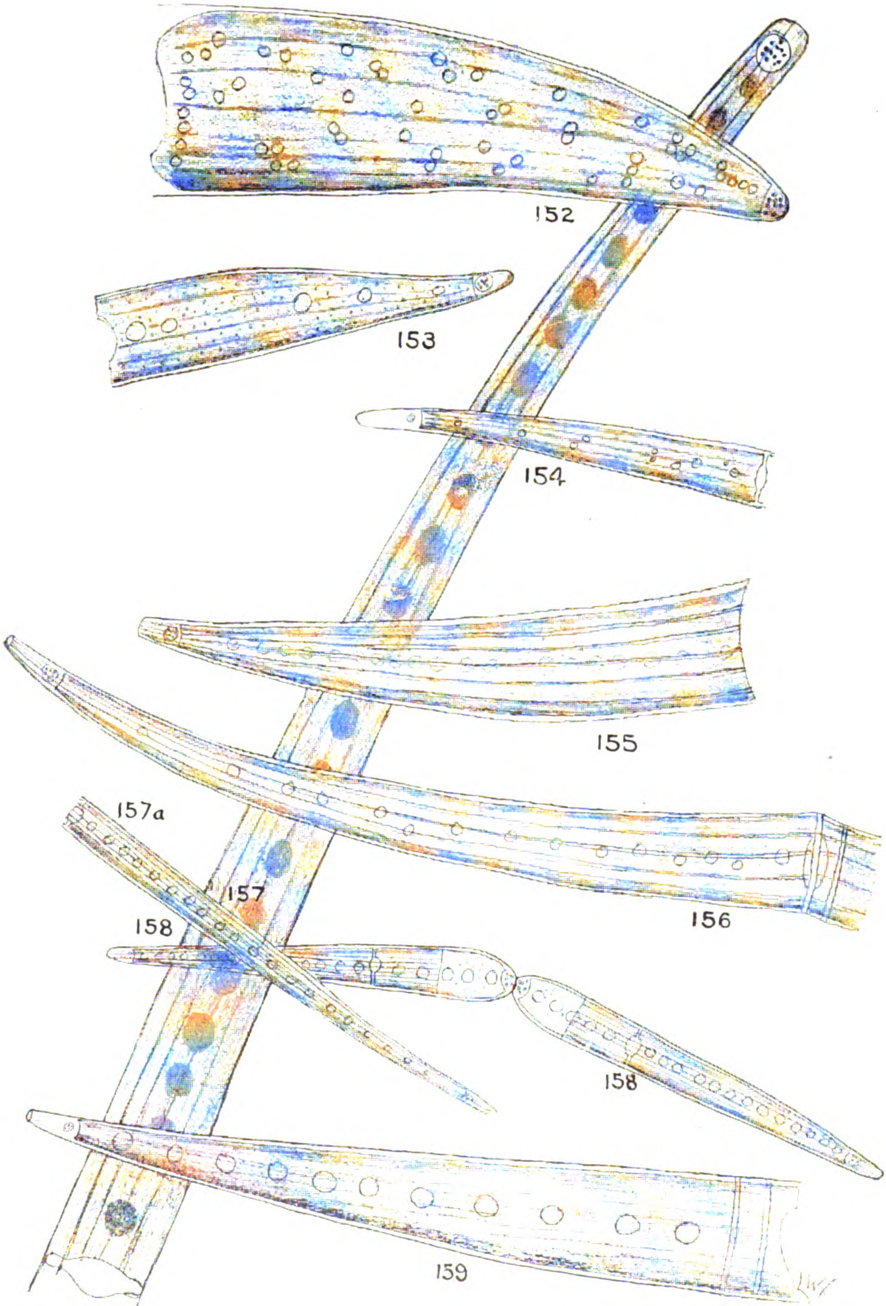
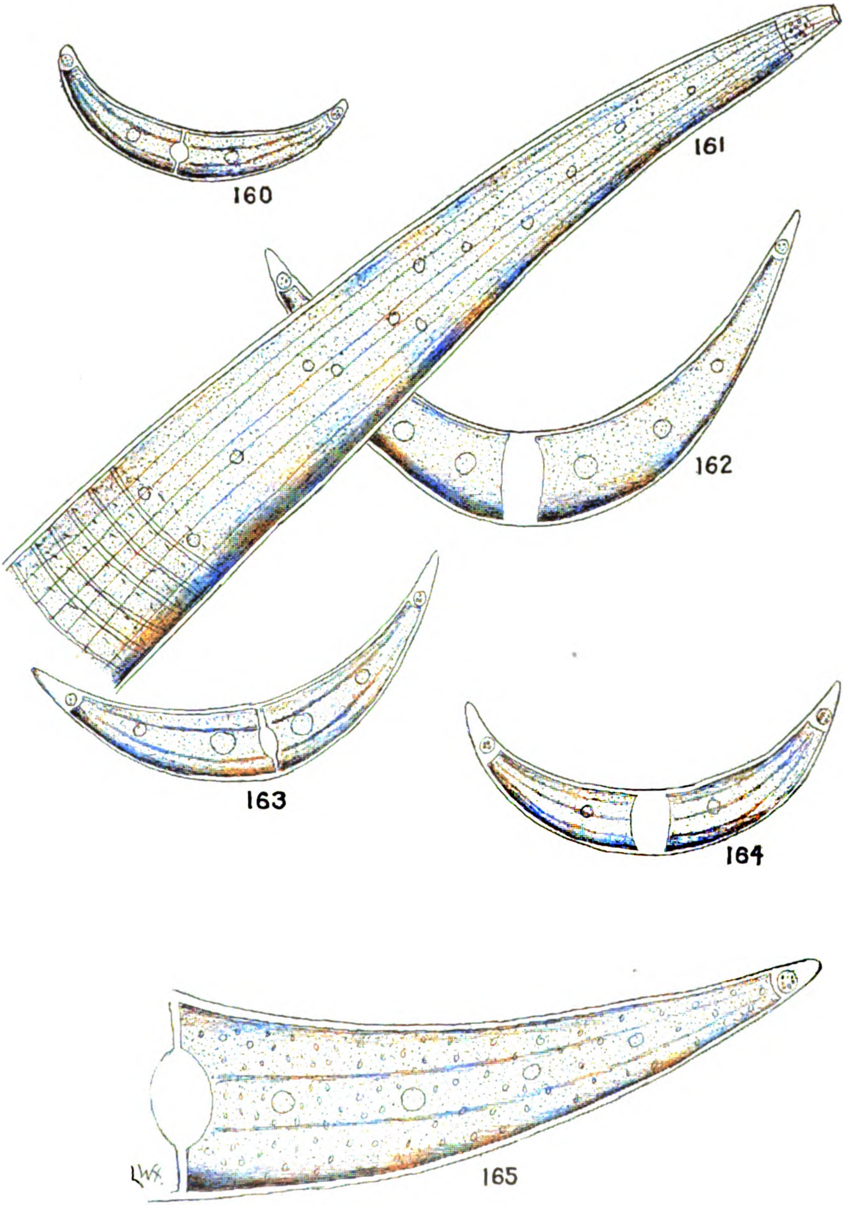


PLATE XXIV; FIGURES 160 TO 165; MAGNIFIED 1000 DIAMETERS, EXCEPT FIG. 161.

PLATE XXIV.



160 161 162 163 164 165

PLATE XXV; FIGURES 166 TO 171; FIGS. 168, 169 MAGNIFIED 500 DIAMETERS; ALL OTHERS 1000 DIAMETERS.

PLATE XXV.

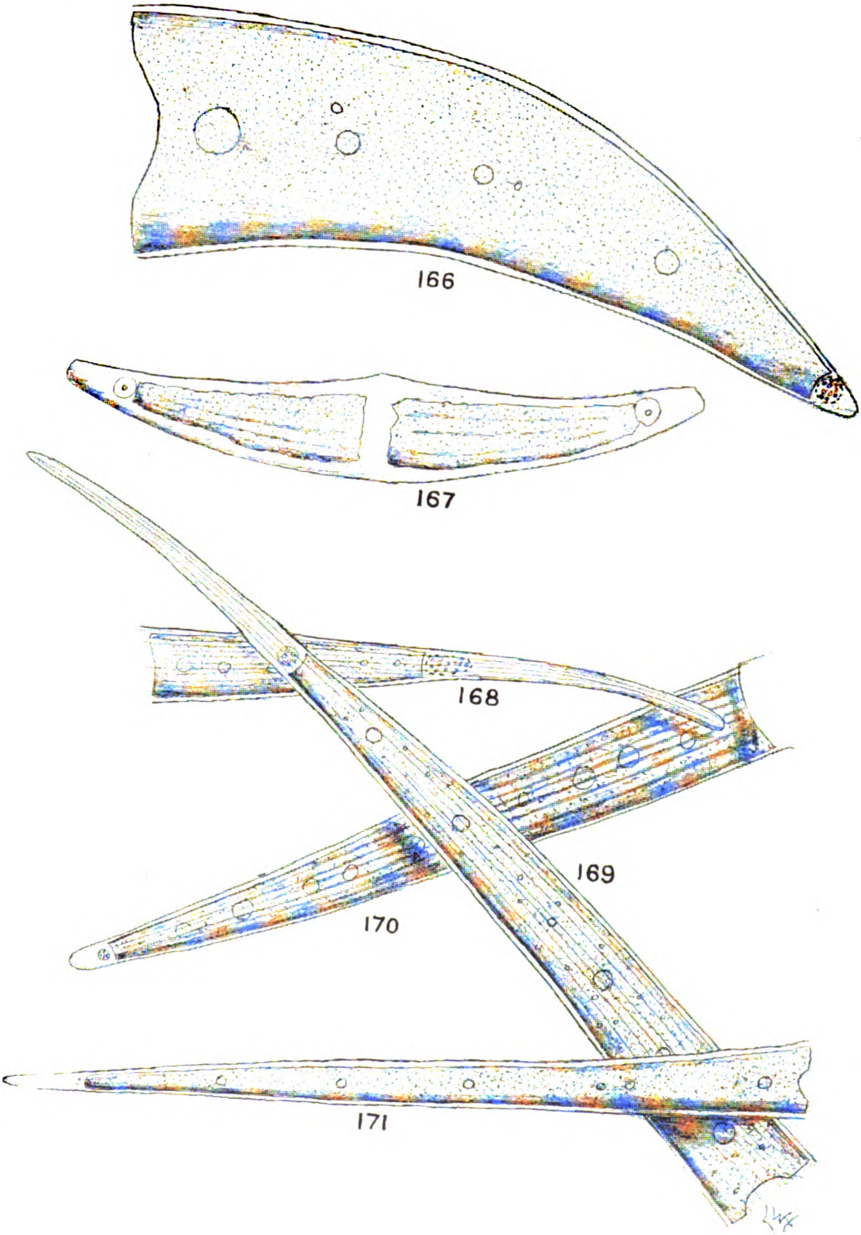
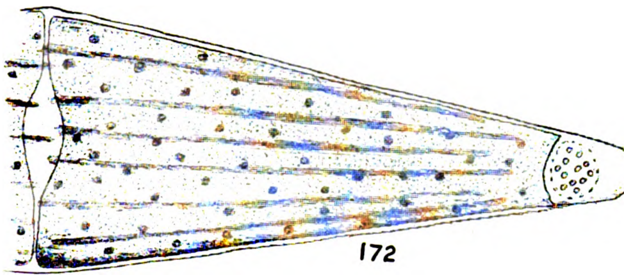


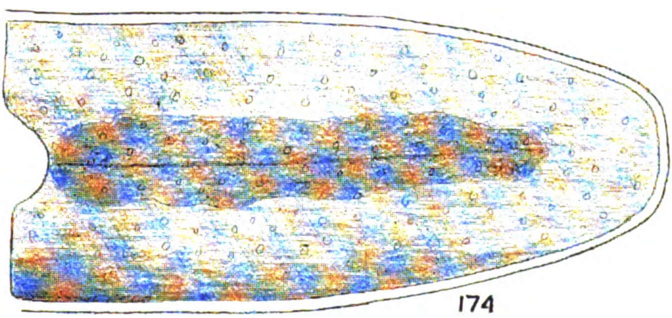
PLATE XXVI; FIGURES 172 TO 175; MAGNIFIED 1000 DIAMETERS.

PLATE XXVI.

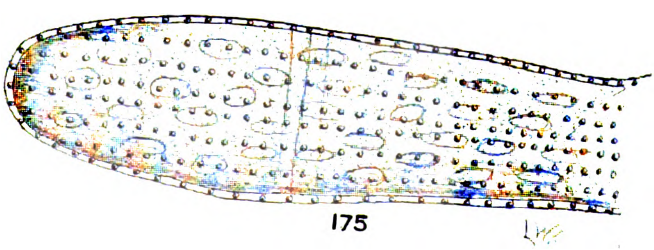


172

173



174

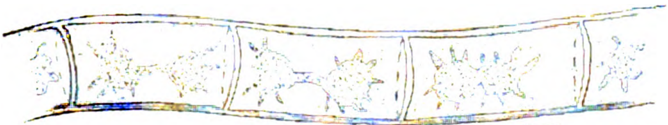


175

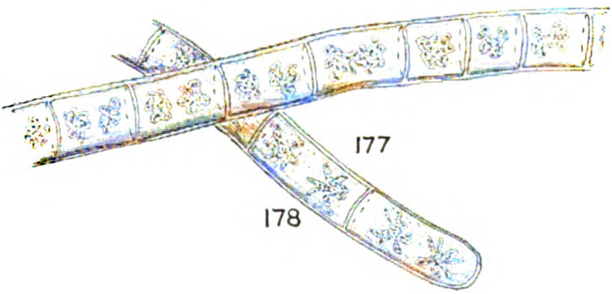
PLATE XXVII; FIGURES 176 TO 180; MAGNIFIED 500 DIAMETERS.

Fig. 176.	*Zygnema leiospermum* D. By. .	page	66
Figs. 177, 178.	*Zygnema stellium* Ag. . .	"	"
Fig. 179.	*Zygnema stellium* var. *genuinum* Kirch.	"	"
Fig. 180.	*Zygnema cruciatum* (Vauch.) Ag.	"	"

PLATE XXVII.



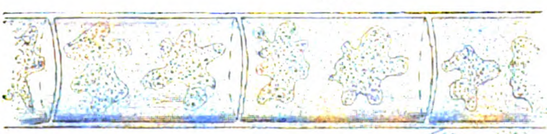
176

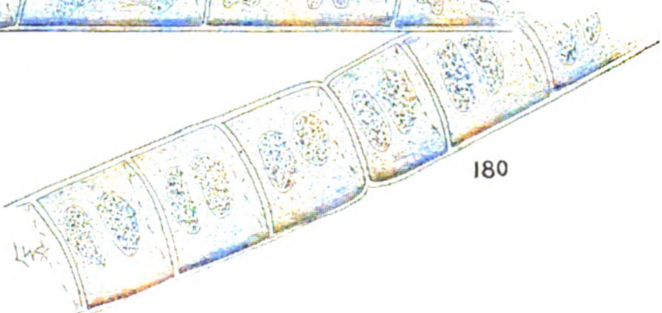


177

178

179





180

PLATE XXVIII; FIGURES 181 TO 187; FIGS. 182, 186 MAGNIFIED 250 DIAMETERS; ALL OTHERS 500 DIAMETERS.

Fig. 181.	*Spirogyra varians* (Hass.) Kütz. .	page 67
Fig. 182.	" " " " Conjugating	" "
Figs. 183, 184.	*Spirogyra Weberi* Kütz. . .	" "
Fig. 185.	*Spirogyra maxima* (Hass.) Witt.	" "
Fig. 186.	" *jugalis* (Dillw.) Kütz. .	" "
Fig. 187.	" " " " Conjugating	" "

PLATE XXVIII.

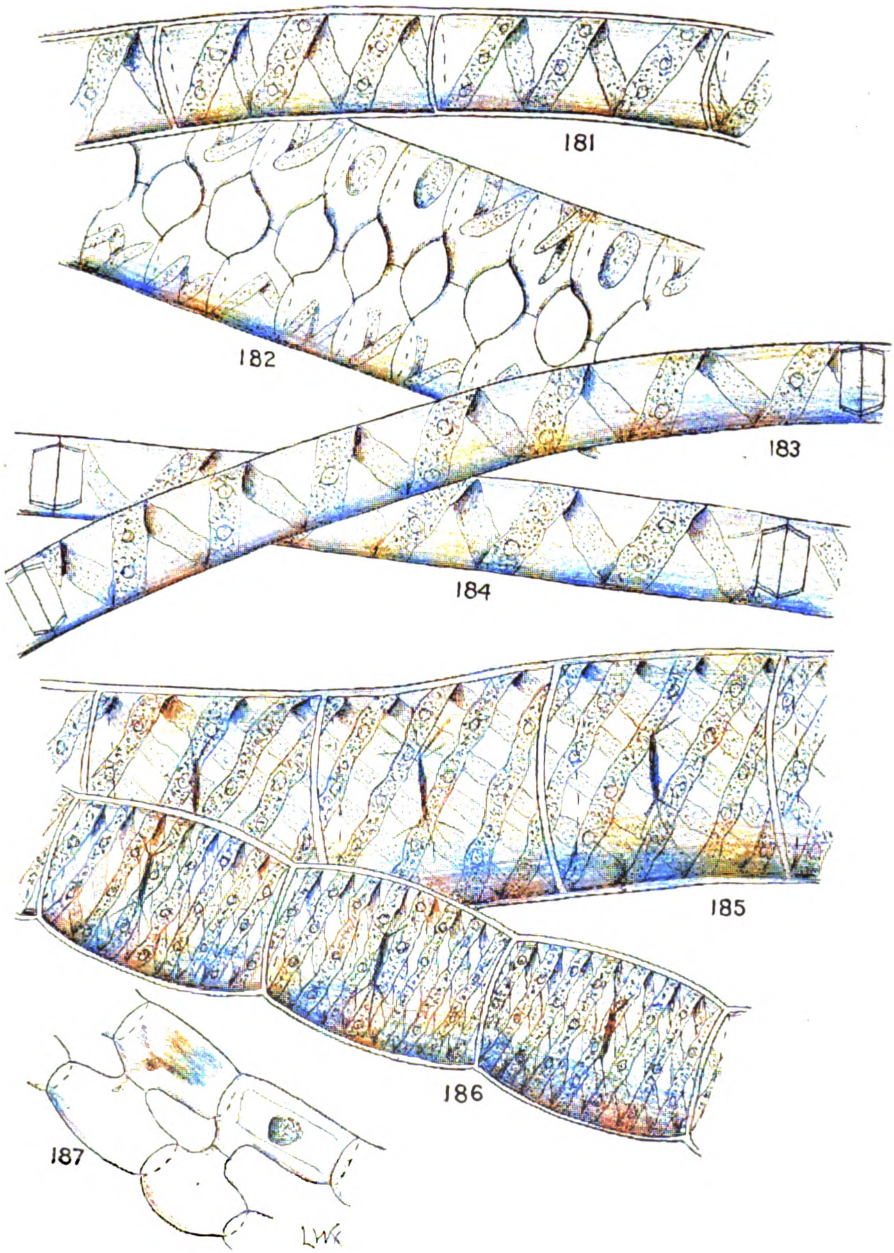


PLATE XXIX; FIGURES 188 TO 196; MAGNIFIED 250 DIAMETERS.

Fig. 188.	*Spirogyra dubia* Kütz. . . .	page 67
Figs. 189, 190.	*Spirogyra quinina* (Ag.) Kütz.	" "
Fig. 191.	*Spirogyra Grevilleana* (Hass.) Kütz.	" "
Fig. 192.	" *majuscula* Kütz. . .	" "
Fig. 193.	" *adnata* Kütz. . . .	" "
Fig. 194.	" *Spreeiana* Rab. . .	" "
Fig. 195.	" *calospora* Cleve . .	" "
Fig. 196.	" *decimina* (Mull.) Kütz.	" "

PLATE XXIX.

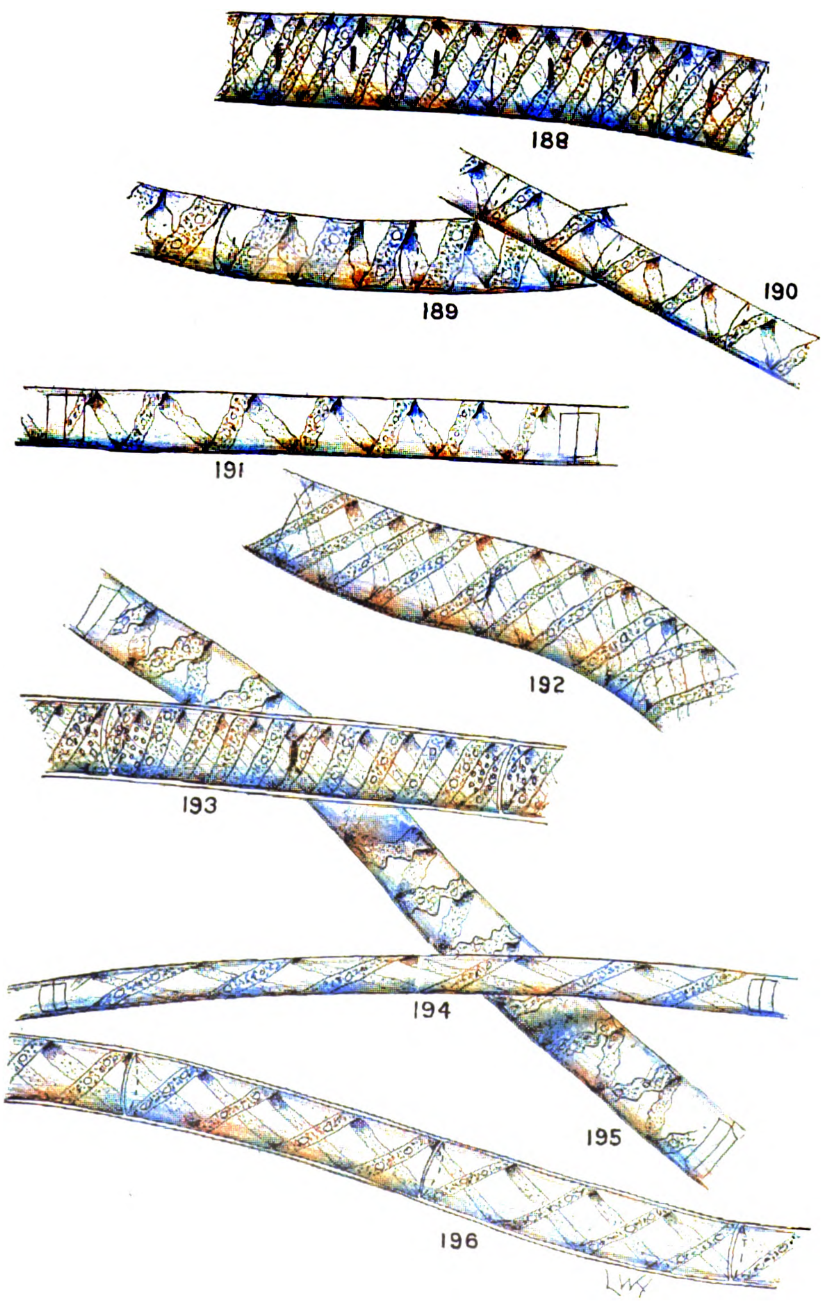


PLATE XXX; FIGURES 197 TO 206; FIGURES 197, 205 MAGNIFIED 500 DIAMETERS; ALL OTHERS 250 DIAMETERS.

Fig. 197.	*Spirogyra communis* (Hass.) Kütz.	page	67
Fig. 198.	" *fluviatilis* Hilse . .	"	"
Fig. 199.	" " " Kept in dishes, the cells elongating without dividing, and dancing dots of oil appearing in the ends		
Fig. 200.	*Vaucheria sessilis* (?) (Vauch.) D. C.	"	55
Fig. 201.	" " " "	"	"
Fig. 202.	*Spirogyra mirabilis* Hass. . .	"	67
Fig. 203.	" *bellis* (Hass.) Cleve. In state of decomposition . . .	"	67
Fig. 204.	*Spirogyra bellis* (Hass.) Cleve .	"	"
Fig. 205.	" *flavescens* (Hass.) Cleve	"	"
Fig. 206.	*Vaucheria.* Showing sexual organs .	"	55

PLATE XXX.

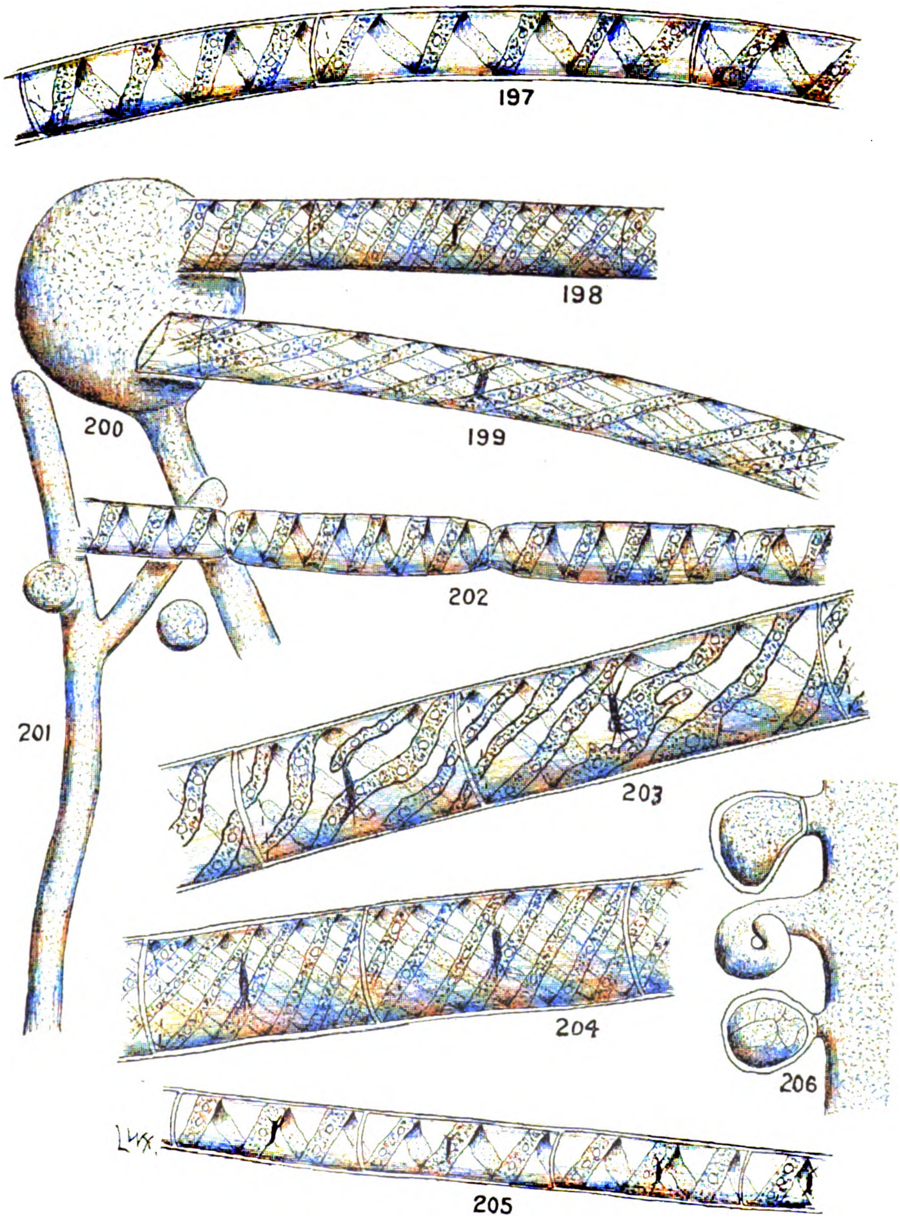
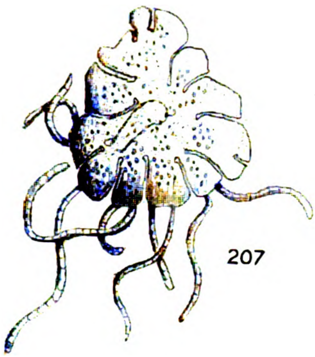
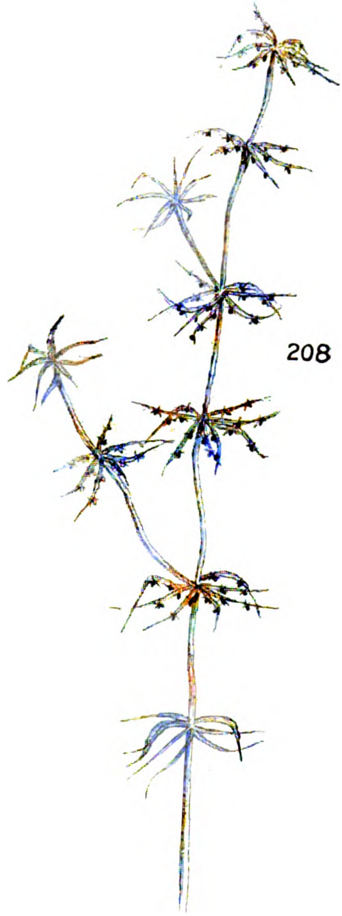


PLATE XXXI; FIGURES 207 TO 209.

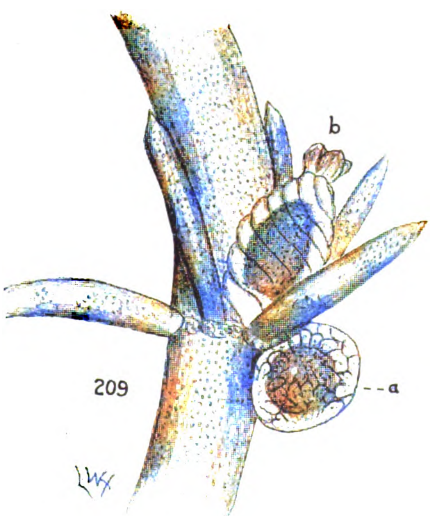
PLATE XXXI.



207



208



209

PLATE XXXII; FIGURES 210 TO 216.

PLATE XXXII.

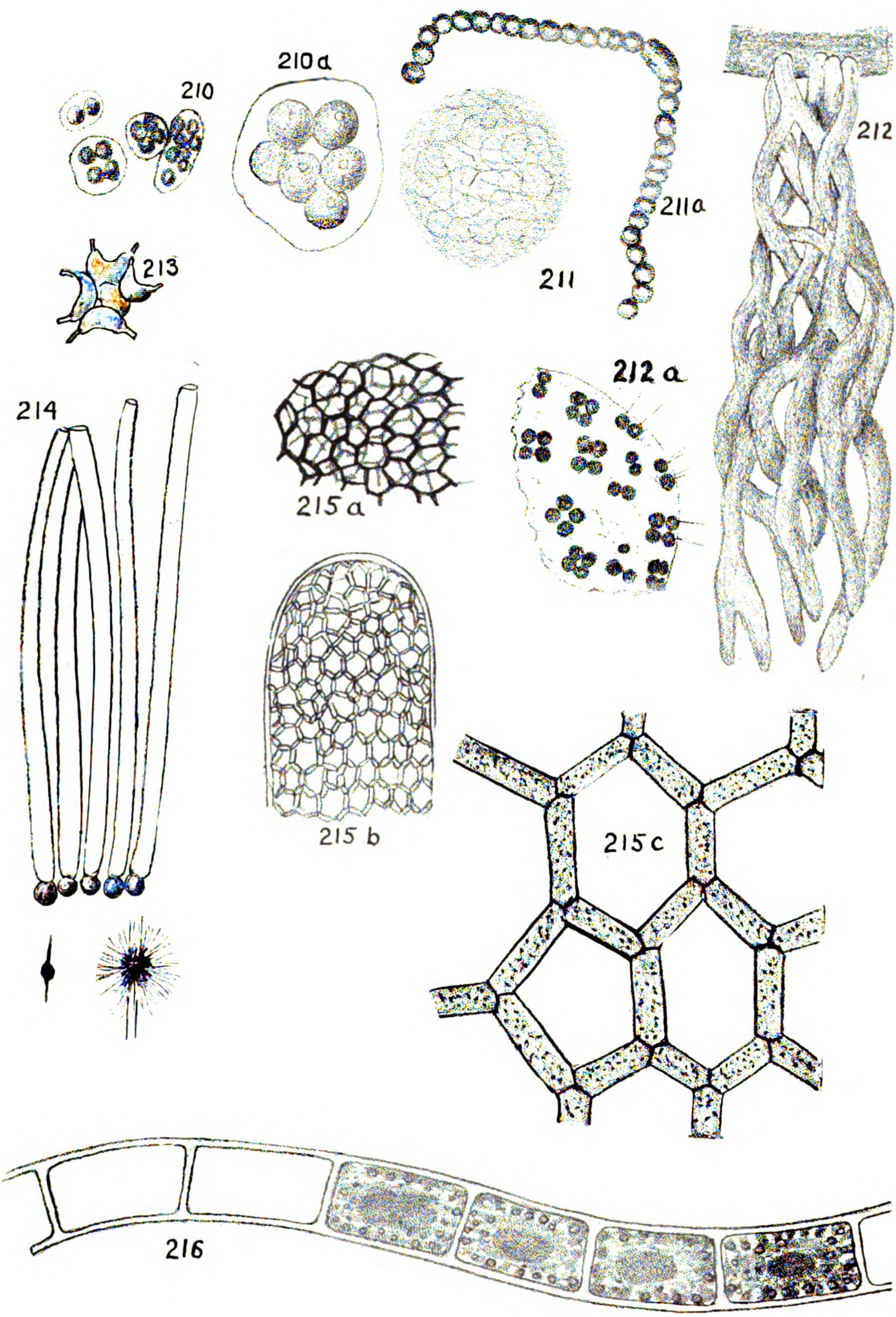
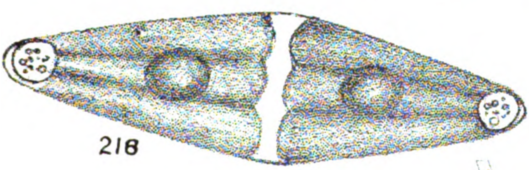


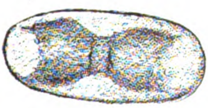
PLATE XXXIII; FIGURES 217 TO 220.

PLATE XXXIII.

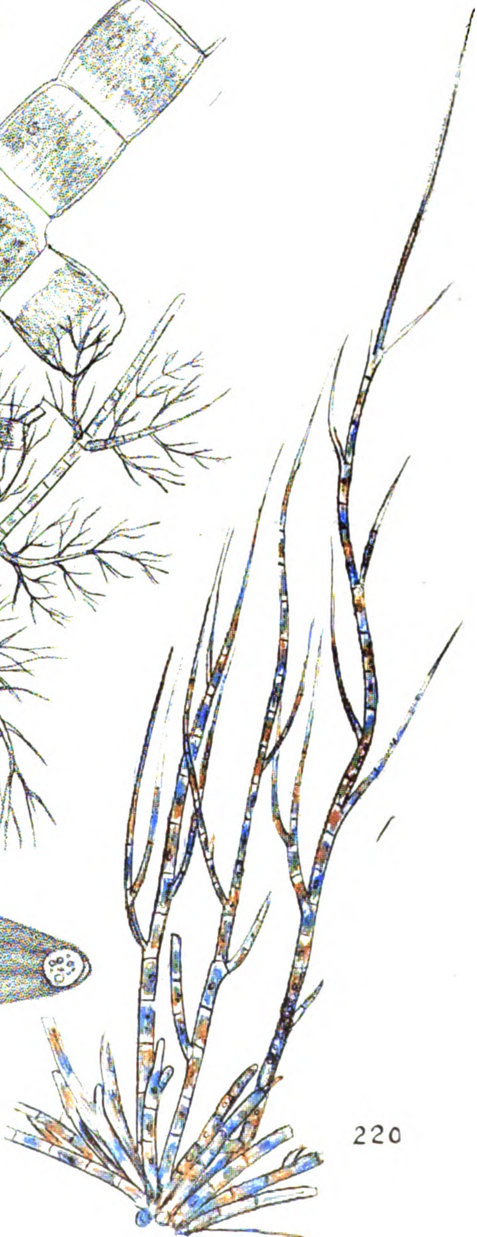
217



218



219

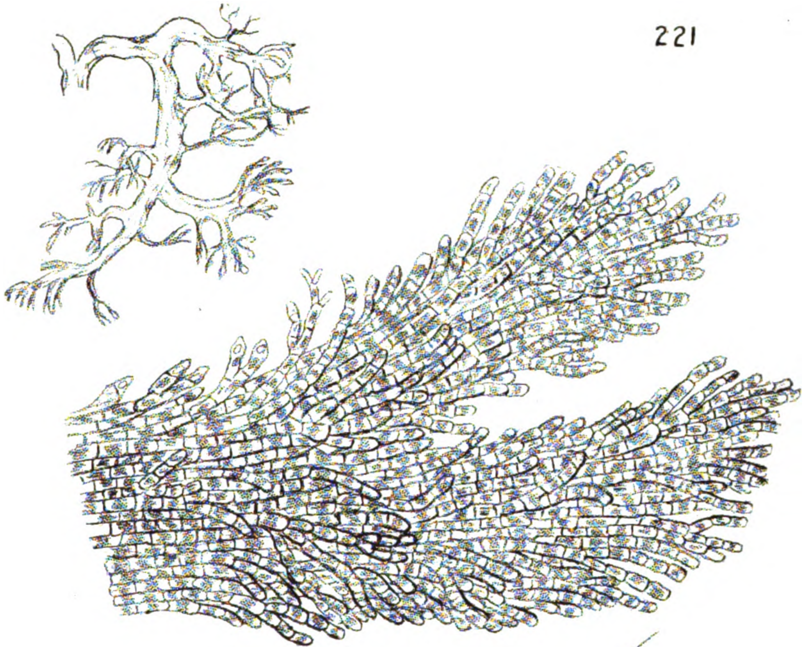


220

PLATE XXXIV; FIGURES 221, 222.

PLATE XXXIV.

221



222

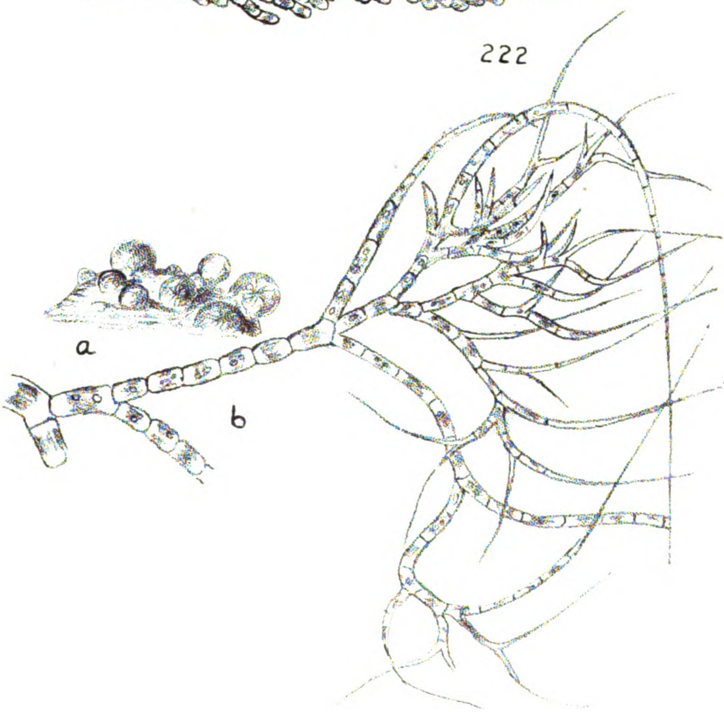


PLATE XXXV; FIGURES 223 TO 228; MAGNIFIED 500 DIAMETERS, EXCEPT FIG. 228.

PLATE XXXV.

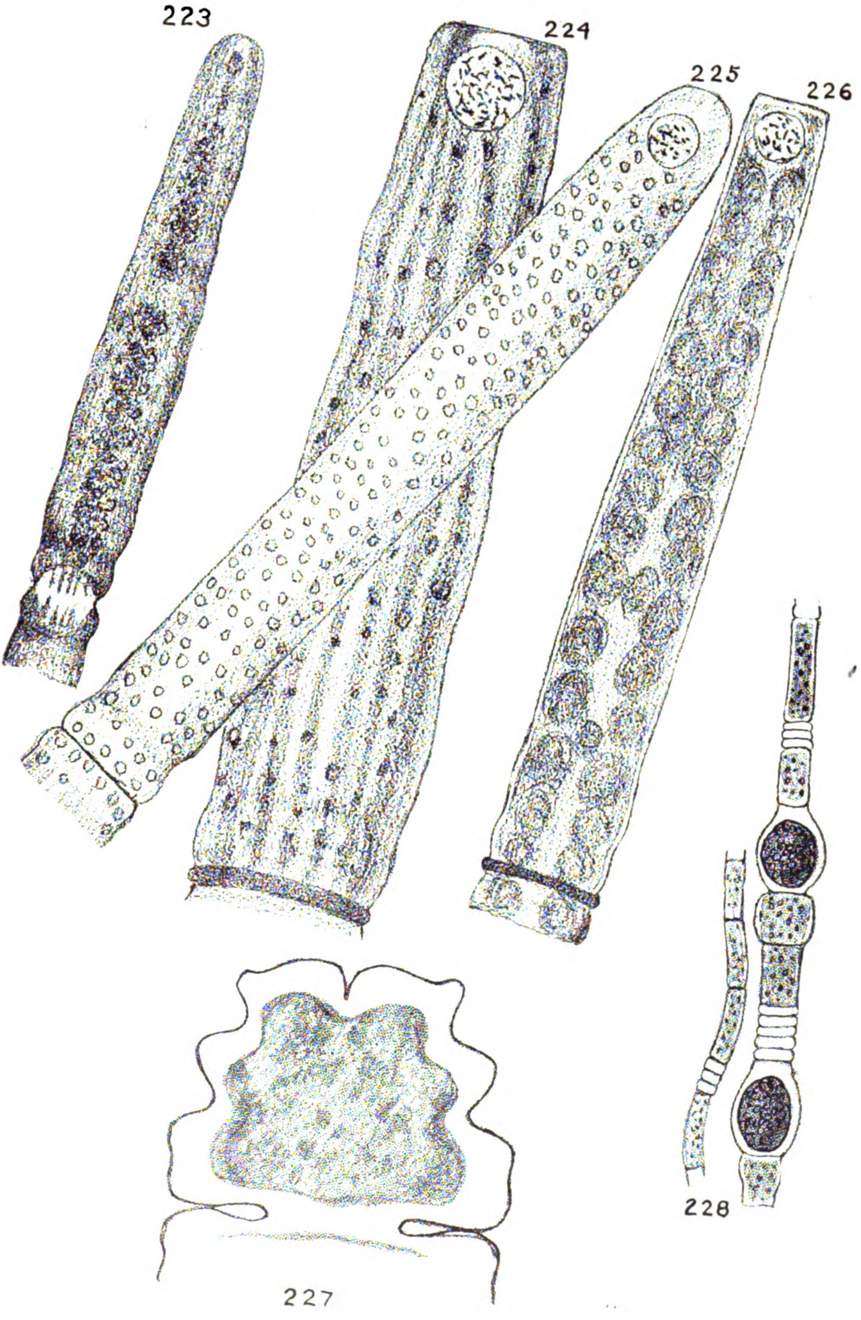


PLATE XXXVI; FIGURES 229 TO 237; MAGNIFIED 1000 DIAMETERS.

Fig. 229.	*Euastrum oblongatum* (Grev.) Ralfs	page	62
Fig. 230.	" *ampullaceum* Ralfs . .	"	"
Fig. 231.	*Staurastrum crenulatum* (Delp.) Näg. End view	"	"
Fig. 231*a*.	*Staurastrum crenulatum* (Delp.) Side view	"	"
Fig. 232.	*Euastrum elegans.* Kütz. . . .	"	"
Fig. 233.	*Staurastrum dejectum* Breb. . .	"	"
Fig. 233*a*.	" " " End view	"	"
Fig. 234.	*Euastrum Nordstedtianum* Wolle .	"	"
Fig. 235.	*Staurastrum margaritaceum* Ehrb. .	"	"
Fig. 235*a*.	" " " Side view	"	"
Fig. 236.	*Staurastrum dejectum* Breb. . .	"	"
Fig. 236*a*.	" " " Side view	"	"
Fig. 237.	" *gracile Ralfs* . .	"	"
Fig. 237*a*.	" " " Side view	"	"

PLATE XXXVI.

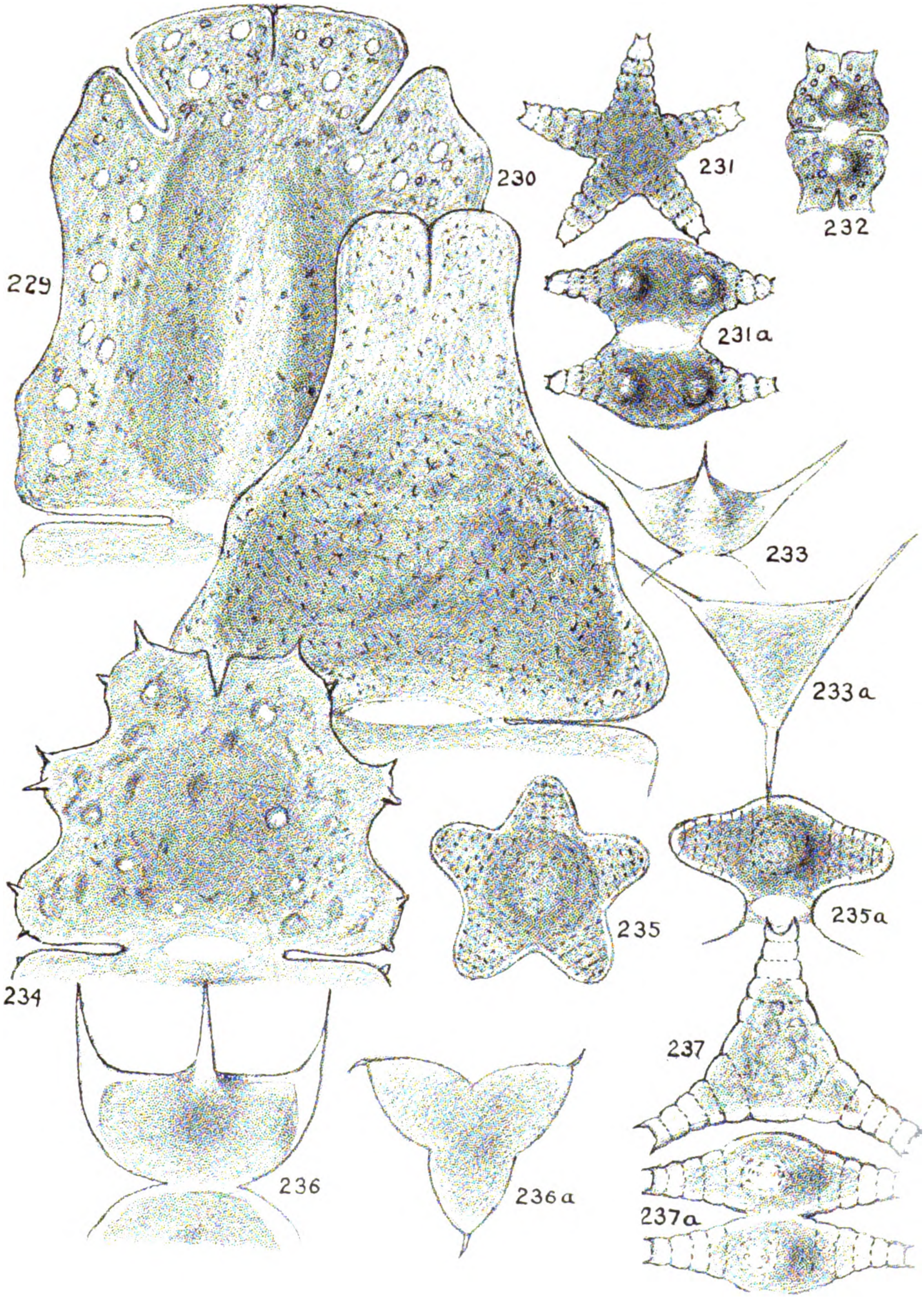


PLATE XXXVII; FIGURES 238 TO 244; MAGNIFIED 500 DIAMETERS, EXCEPT FIGS. 243, 244.

PLATE XXXVII.

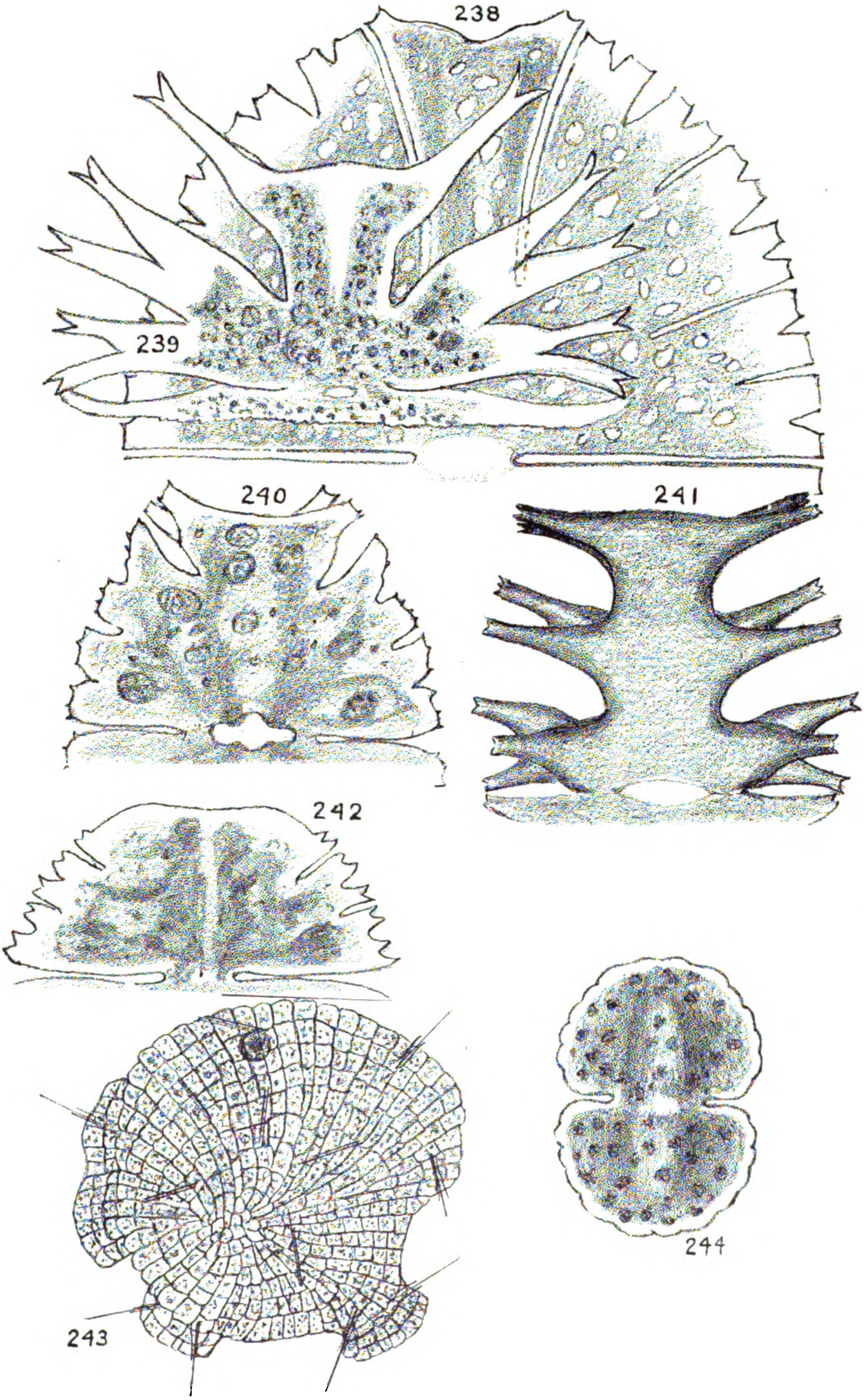


PLATE XXXVIII; FIGURES 245 TO 253; MAGNIFIED 1000 DIAMETERS.

Fig. 245.	*Cosmarium ovale* Ralfs . . .	page	64
Fig. 246.	" *pyramidatum* Bréb. .	"	"
Fig. 247.	" *Meneghinii* Bréb. .	"	"
Fig. 248.	" *octhodes* Nord. . .	"	"
Fig. 249.	" *perforatum* Lund. .	"	"
Fig. 250.	" *Nägelianum* Bréb. .	"	"
Fig. 251.	" *intermedium* Delp. .	"	"
Fig. 252.	" *Portianum* Arch. .	"	"
Fig. 253.	" *orbiculatum* Ralfs .	"	"

PLATE XXXVIII.

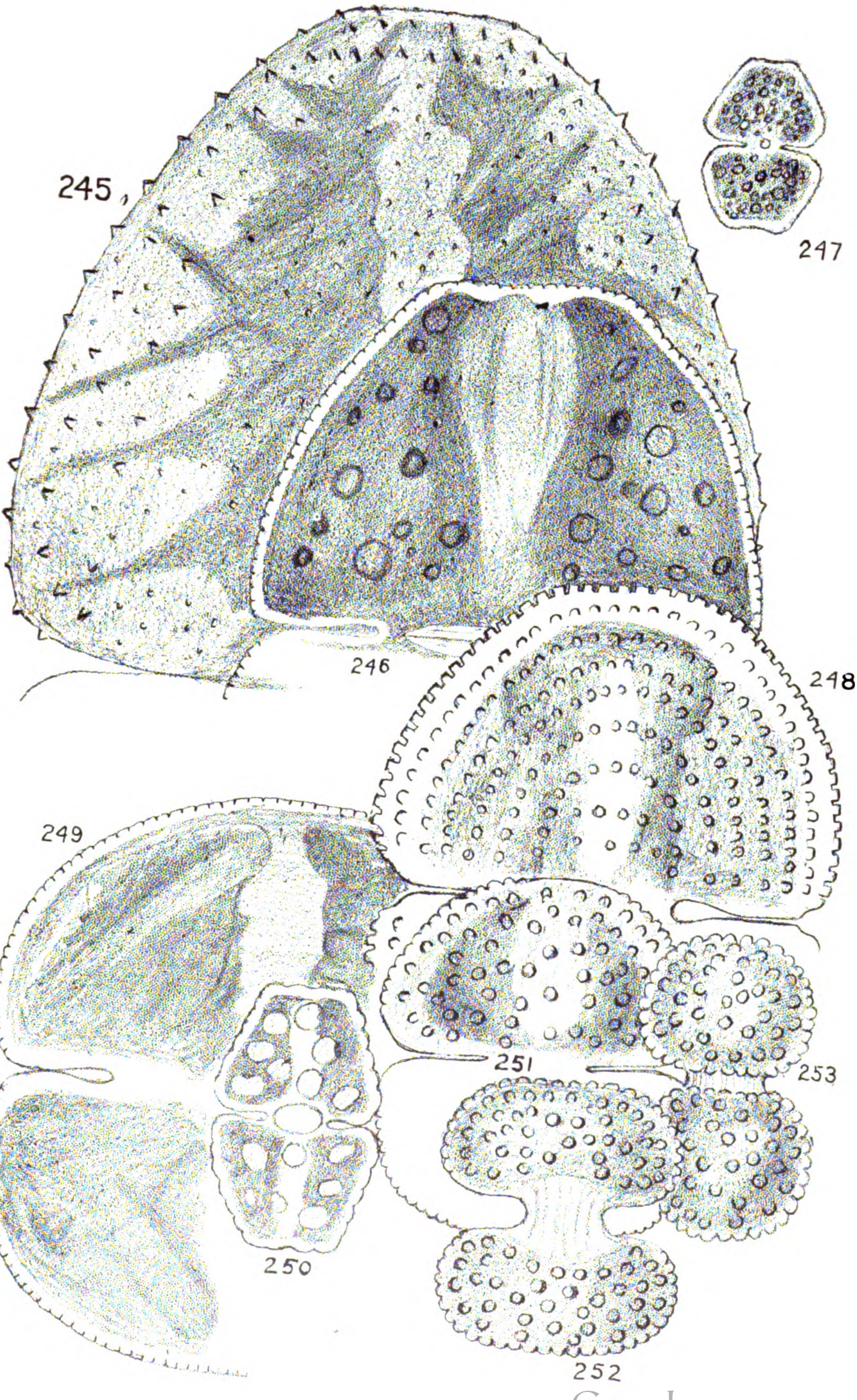


PLATE XXXIX; FIGURES 254 TO 260; MAGNIFIED 1000 DIAMETERS.

PLATE XXXIX.

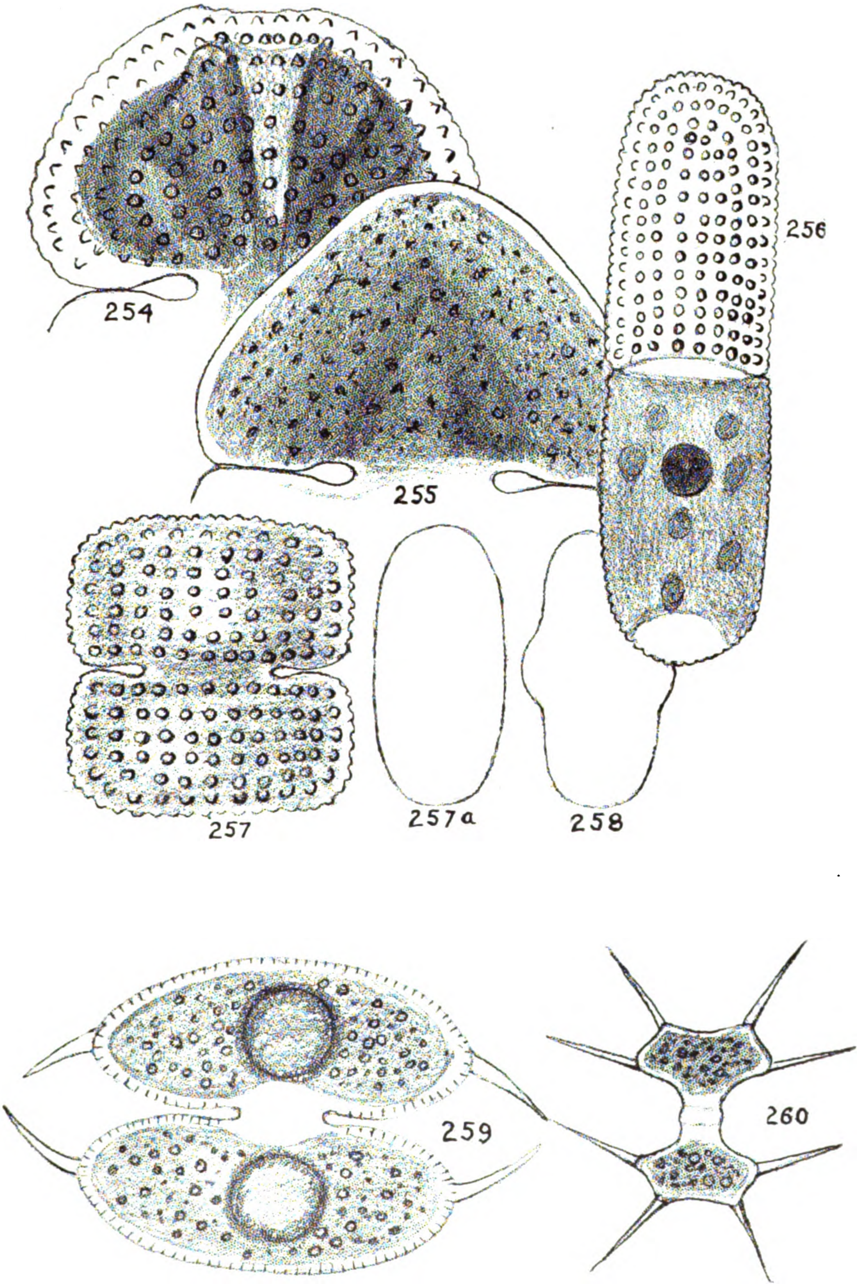


PLATE XL; FIGURES 261 TO 266; MAGNIFIED 1000 DIAMETERS.

PLATE XL.

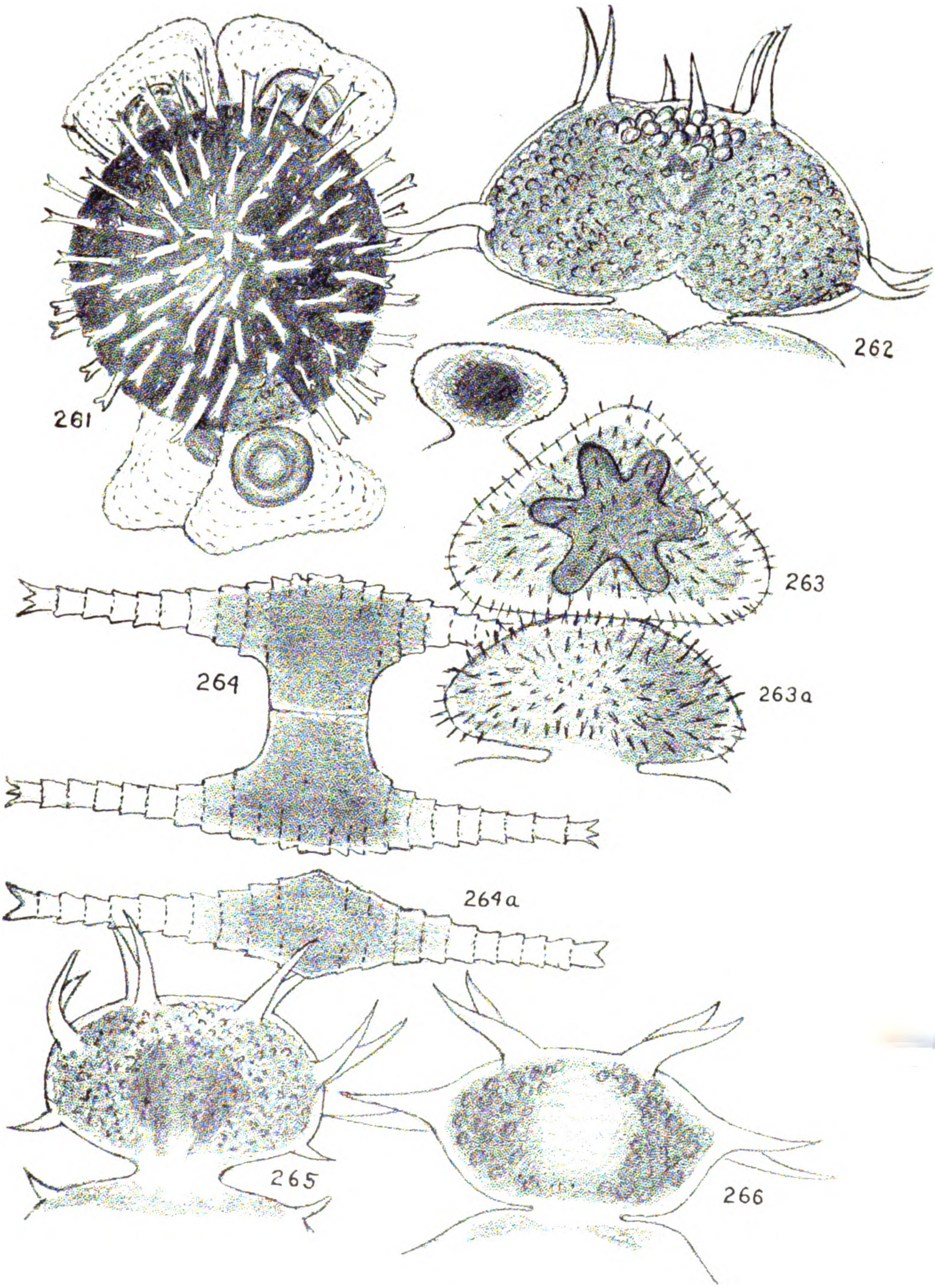
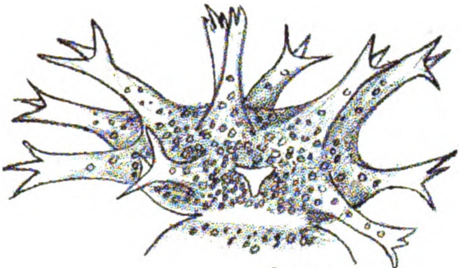
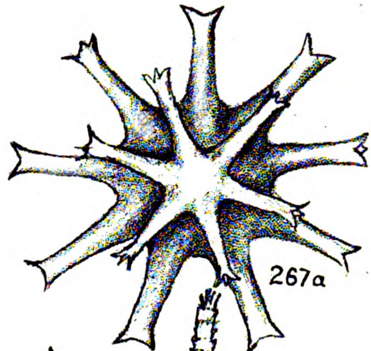
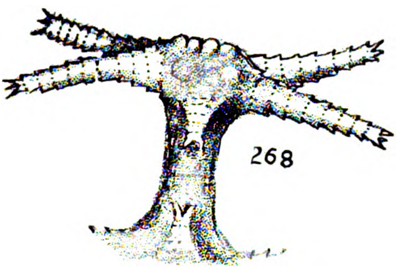


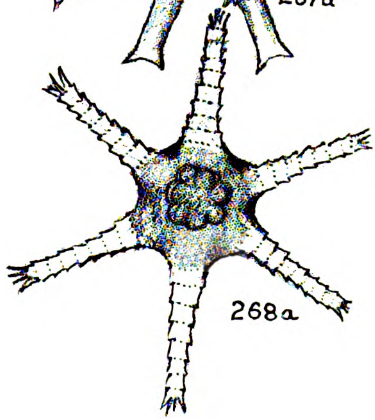
PLATE XLI; FIGURES 267 TO 270; MAGNIFIED 500 DIAMETERS.

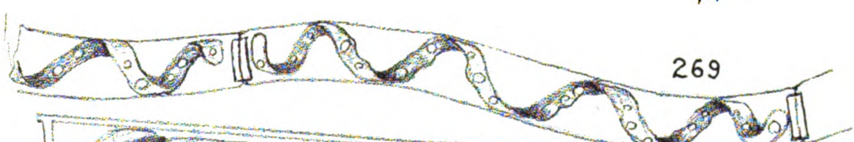
PLATE XLI.


267


267a


268


268a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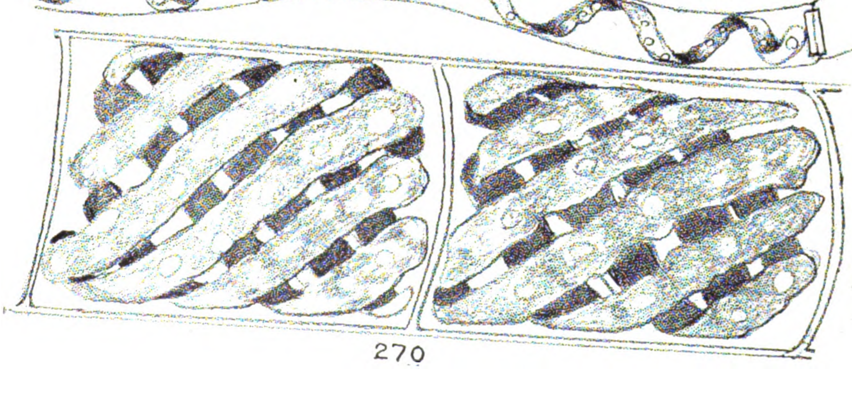

270

PLATE XLII; FIGURES 271 TO 277; MAGNIFIED 500 DIAMETERS.

PLATE XLII.

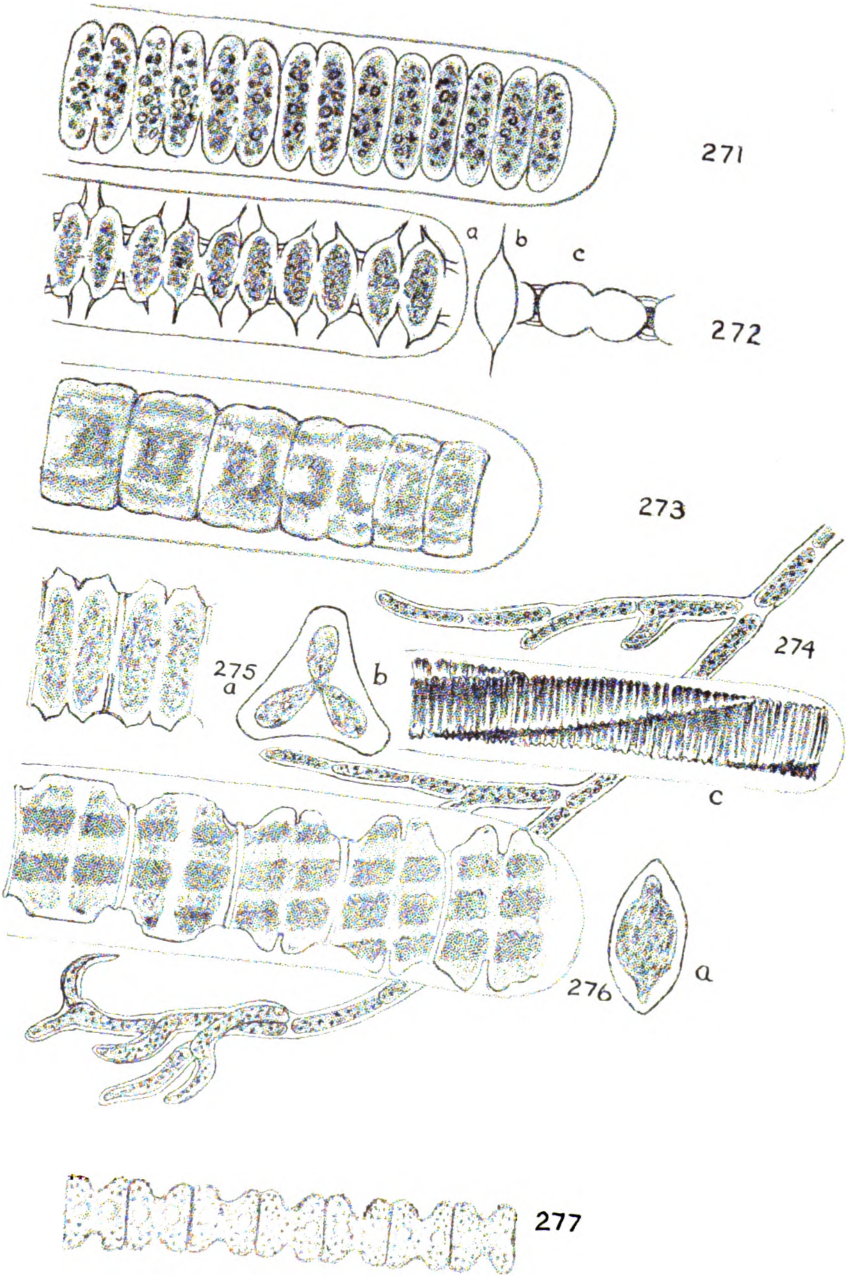
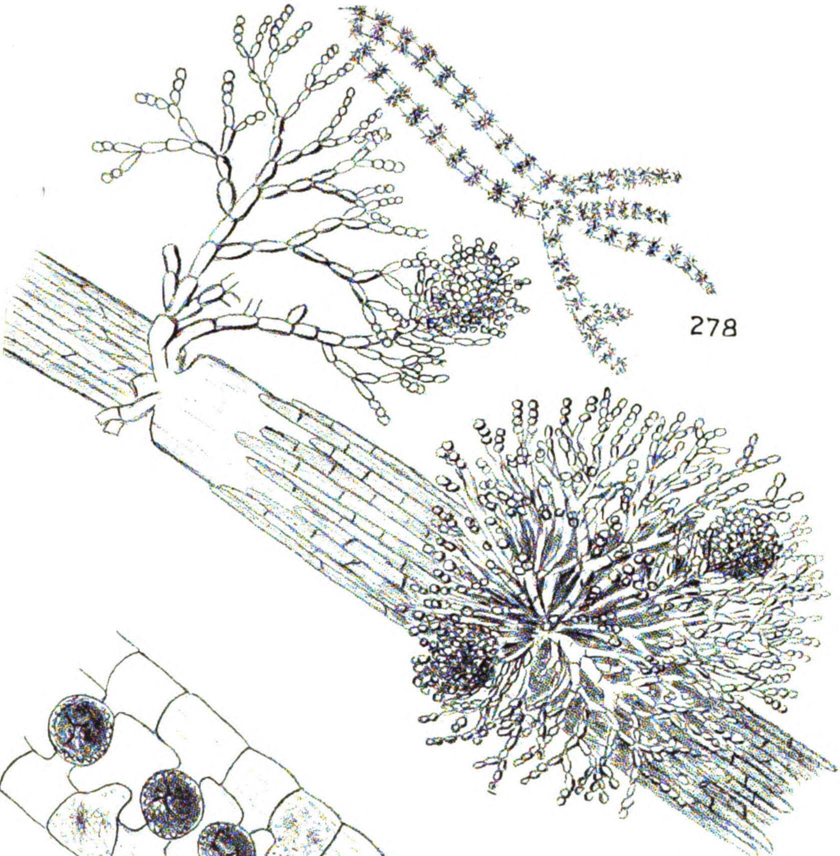


PLATE XLIII; FIGURES 278 TO 280.

PLATE XLIII.



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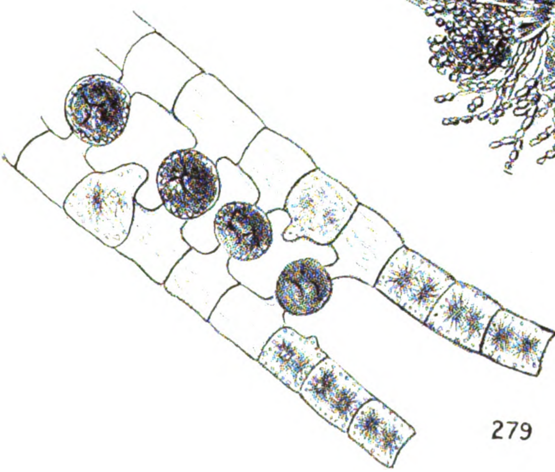

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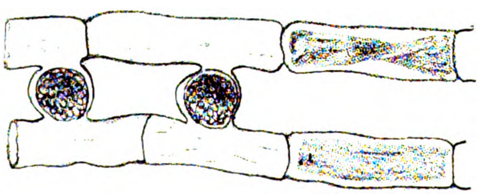
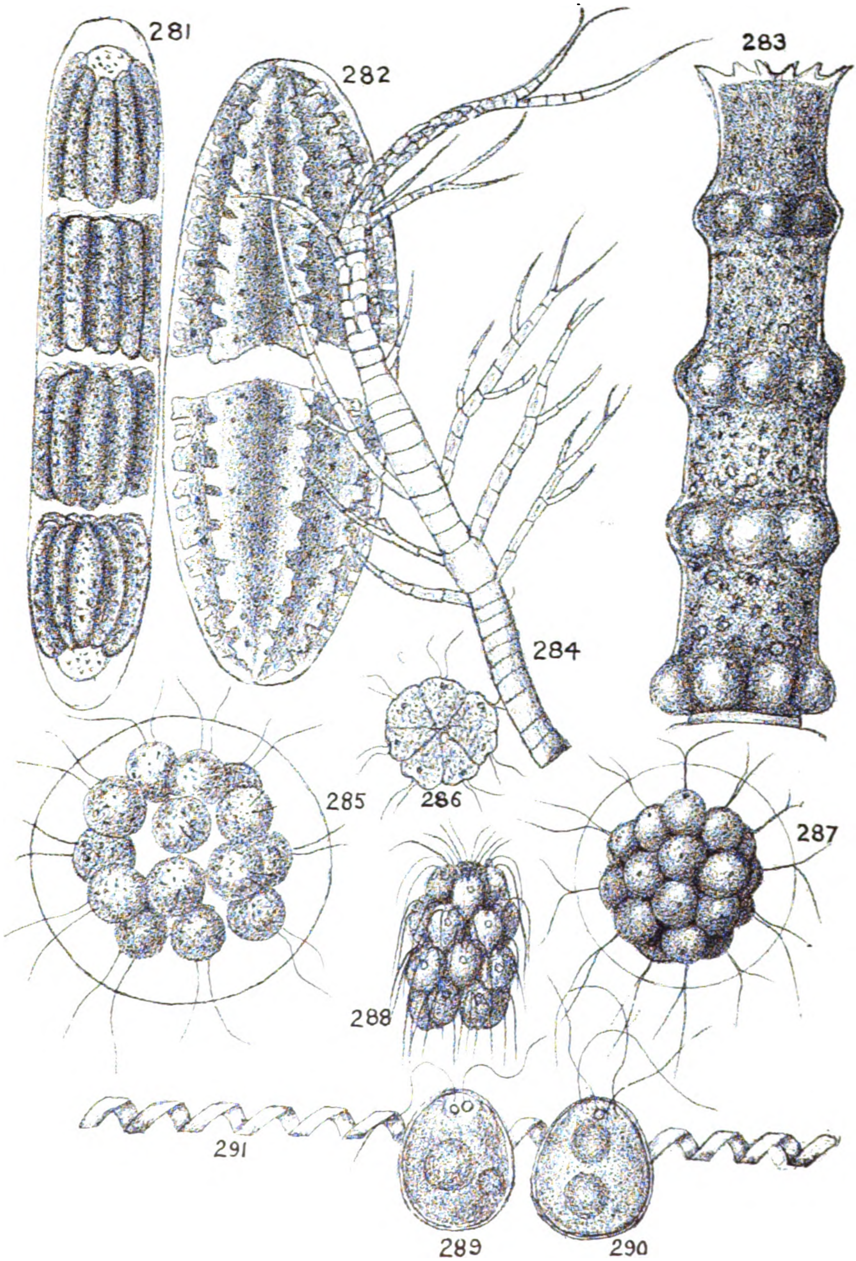


Plate XLIV; Figures 281 to 291; Magnified 1000 Diameters.

PLATE XLIV.



CATALOGUE SLIPS.

Connecticut. *State geological and natural history survey.*

Bulletin no. 11. The bryophytes of Connecticut. By A. W. Evans and G. E. Nichols. Hartford, 1908.

203 pp., 23^{cm}.

Evans, Alexander William, and ***Nichols, George Elwood.***

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Botany.

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BULLETIN No. 11

HARTFORD
Printed for the State Geological and Natural History Survey
1908

THE

BRYOPHYTES OF CONNECTICUT

By

ALEXANDER WILLIAM EVANS, Ph.D.,

Professor of Botany, Yale University

AND

GEORGE ELWOOD NICHOLS, B.A.,

Assistant in Botany, Yale University

HARTFORD

Printed for the State Geological and Natural History Survey

1908

PREFACE

The plants treated in the present report are largely neglected by collectors, partly on account of their small size and the difficulties encountered in their identification, partly on account of their slight value from an economic standpoint. To the student of botany, however, and especially to the morphologist and taxonomist, they are of exceptional interest. The morphologist finds among them all gradations between simple and more complex types of structure, and is thus enabled to gain some idea of the way in which the higher plants may have been derived from the lower; while the taxonomist obtains from them a series of distinct and attractive genera and species, which offer for his solution many complicated problems in variation and geographical distribution. In presenting to the botanists of Connecticut some account of the work which has been done on the Bryophytes within the state, it is hoped that more interest in this neglected group of plants may be aroused.

The report includes a general description of the Bryophytes as a whole and of the six subdivisions or orders into which it seems advisable to divide them. It also contains keys, more or less artificial, to aid in the identification of those species which have been detected in Connecticut. But it makes no attempt to describe or illustrate the genera and species represented, and is not intended as a substitute for the works in which such descriptions and illustrations are to be found. The student who makes a careful study of our Mosses and Hepatics will still find it necessary to use books of this character in order to confirm the determinations made by the keys, but the report should make the work of determination more decisive by indicating which species are to be expected in our region. The various books, articles, and scattered notes, which relate directly to Connecticut Bryophytes, are listed in

the bibliography at the close of the report. The following recent works (not included in the bibliography) may also be recommended: —

1. Braithwaite, R. The British Moss-Flora. Vol. I, pp. x + 315. 45 plates. Vol. II, pp. 268. Plates 46-84. Vol. III, pp. 274. Plates 85-128. Large 8vo. London, 1887-1905.

2. Howe, M. A. The Hepaticæ and Anthocerotes of California. Mem. Torrey Club, 7: 1-208. Pl. 88-122. 1899.

3. Warnstorf, C. Kryptogamenflora der Mark Brandenburg. Band I. Leber- und Torfmoose. pp. xvi + 481. Band II. Laubmoose. pp. xii + 1160. Fully illustrated by text-figures. Leipzig, 1902-1906.

4. Dixon, H. N., and Jameson, H. G. The Student's Handbook of British Mosses. Second Edition, pp. xlix + 586. 65 plates. 8vo. Eastbourne and London, 1904.

5. Roth, G. Die europäischen Laubmoose. Band I. pp. xiii + 598. 52 plates. Band II. pp. xvi + 733. 62 plates. Large 8vo. Leipzig, 1904-1905.

6. Roth, G. Die europäischen Torfmoose. pp. viii + 80. 11 plates. Large 8vo. Leipzig, 1906.

7. Müller, C. Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz. 2. Auflage. Band VI. Die Lebermoose. Incomplete. Six fascicles, comprising 384 pp. and 225 text-figures, have already been published. Leipzig, 1906-1908.

In the study of certain critical families and genera the writers have received much assistance from Mrs. Elizabeth G. Britton, of the New York Botanical Garden, Mr. C. Warnstorf, of Berlin, Germany, and Mr. J. Cardot, of Charleville, France. Other correspondents, who will be mentioned particularly in the catalogue of species, have kindly furnished material of Connecticut Bryophytes for examination, and have thereby made the report much more complete than it would otherwise have been. To all of these the writers would express their sincere thanks.

BOTANICAL LABORATORY,
SHEFFIELD SCIENTIFIC SCHOOL.

CONTENTS

THE BRYOPHYTES OF CONNECTICUT

GENERAL CHARACTERISTICS OF THE BRYOPHYTES

The Bryophytes represent a very clearly defined Class in the Vegetable Kingdom, occupying a position just below the Pteridophytes, which include the Ferns and their allies. They comprise the plants which are properly known as Mosses and Liverworts. They must not be confused, however, with Algæ and Lichens, both of which are sometimes called mosses, although simpler and less definite in organization, nor yet with the more highly developed Club Mosses, which belong to the Pteridophytes. The group is characterized by a clearly defined alternation of generations and by complex sexual organs, both antheridia and archegonia being multicellular, and showing a differentiation into sterile and fertile cells.

The *gametophyte,* or sexual individual, is a green plant, capable of absorption from the outside and therefore able to lead an independent life. It constitutes the plant-body of the Moss or Liverwort as ordinarily understood, and is usually much larger and more conspicuous than the *sporophyte,* or asexual individual. It consists of a dorsi-ventral thallus, usually closely appressed to the substratum, or else of a leafy shoot, the leaves being always destitute of stalks, and usually but a single cell thick throughout the greater part of their extent. Whatever its form the gametophyte exhibits an apical growth, frequently dying at one end while it advances at the other. It develops no true root, as do the higher plants, but clings to the substratum by means of filamentous organs called *rhizoids,* which often play no part in the process of absorption. The antheridia and archegonia are borne on the gametophyte; in monoicous species they arise on the same plant; in dioicous species, on different plants. The *antheridium* consists of a spheroidal or ovoid sac, sometimes stalkless and sometimes

borne on a short stalk. The sac is bounded on the outside by a wall composed of a single layer of sterile cells, and the whole interior is occupied by a compact mass of fertile cells, each one of which gives rise to a single male cell, or *sperm.* When the antheridium is mature, it absorbs water and bursts its wall, allowing the sperms to escape and swim away. Each sperm consists of a slender body, and swims by means of two long and delicate cilia attached at one end.

The *archegonium* may also be stalkless or borne on a short stalk, but is more slender than the antheridium. The single female cell, or *egg,* is developed in the swollen basal portion which is called the *venter,* and this is tipped with a somewhat longer cylindrical portion called the *neck.* Both venter and neck are bounded on the outside by a wall composed of sterile cells. The egg represents the lowest of a row of cells enclosed by this wall, the remaining cells, which fill the neck and a portion of the venter as well, being known as *canal cells.* When the mature archegonium absorbs water, the neck opens at the tip, and the canal cells break down into a mass of slime, some of which escapes through the opening. In this way a free canal is formed which leads from the outside into the venter, and at the base of this canal the egg becomes rounded off. The sperms, attracted by the protoplasmic slime exuding from the archegonium, swim toward it, and one of them makes its way down the canal, uniting with the egg and thus completing the process of fertilization.

As soon as this has been accomplished, the fertilized egg, without escaping from the archegonium, begins at once to develop into the sporophyte, which remains in contact with the gametophyte during its entire life, without being organically connected with it. The chief function of the sporophyte is to develop asexual *spores,* but some of its cells invariably remain sterile and perform functions not connected with reproduction. In the more primitive Bryophytes it is practically destitute of chlorophyll, and is therefore wholly dependent upon the gametophyte for food, living as a parasite upon it. In the higher forms it develops green cells, capable of performing photosynthesis, and probably derives nothing from the gametophyte except solutions of inorganic substances. In such cases the parasitism is only partial. The portion of the

sporophyte which remains in close contact with the gametophyte usually forms a special absorbing organ, or *foot*. This organ, however, never acquires the power of absorbing from the outside, so that the sporophyte is never able to exist as an entirely independent plant.

The spores are borne within a closed case, or *capsule*, which constitutes the so-called *fruit* in the Bryophytes. The capsule is bounded on the outside by a sterile wall, and the space in which the spores are developed is known as the *spore cavity*. When the spores are mature, they lie loose within the cavity, and are set free by the rupturing of the wall. In the majority of cases the capsule is borne on a slender cylindrical *stalk*, which connects it with the foot and at the same time lifts it above the gametophyte.

When the fertilized egg begins to divide, the sterile cells which form the wall of the venter also undergo divisions and develop into a protective covering for the young sporophyte. This covering is called the *calyptra*, and for a considerable period its growth keeps pace with that of the sporophyte. Sooner or later, however, it ceases to enlarge and is eventually ruptured by the swelling capsule. The neck of the fertilized archegonium plays no part in the development of the calyptra, but can frequently be detected at its apex in a shriveled condition. In a few specialized genera a true calyptra is not formed.

Upon germination a spore at first gives rise to an embryonic structure, or *protonema*, upon which the characteristic gametophyte afterwards develops. The protonema is sometimes very short-lived, but in many species persists for a considerable period. It usually consists of a copiously branched filamentous structure, but it may be composed of a flat layer of cells or of a small solid cell mass. In some cases the protonema is represented by a very few cells arranged in a simple cell row and is then scarcely distinguishable.

Although very few Bryophytes are truly aquatic, it has been shown that the presence of water is necessary for the process of fertilization. It not only enables the antheridia and archegonia to open, but it also affords a medium in which the motile sperms can swim. The water is usually supplied by rain, but, if no rain falls at the proper time, the antheridia and archegonia gradually shrivel away and sporophytes fail to

be developed. Any failure to effect fertilization is of course a menace to the further existence of a species, and the probability of failure is especially great in the case of dioicous species, where the male and female plants are often far apart, necessitating a long journey for the sperms. To a certain extent the danger is overcome by the development of organs of vegetative reproduction, known as *gemmæ* or *propagula.* The simplest of these consist of single cells or of small groups of cells without definite form. They easily become separated from the parent plant and develop into new individuals if supplied with the proper conditions. In many cases the reproductive bodies are more complex and already show, even before they fall away, some indication of the thallus or leafy shoot into which they will develop. Certain species reproduce largely if not entirely by means of these vegetative bodies.

It is customary to divide the Bryophytes into two subclasses, known respectively as the Hepaticæ, or Liverworts, and the Musci, or Mosses. This classification, however, as Underwood and others have pointed out, does not altogether represent the facts, and it is more convenient, if not more natural, to divide the group into the following six orders, which may be considered as approximately equal in rank:— I. MARCHANTIALES; II. JUNGERMANNIALES; III. ANTHOCEROTALES; IV. SPHAGNALES; V. ANDREÆALES; VI. BRYALES. By adopting this course it becomes much more practicable to assign definite characters to the various subdivisions. Of these six orders the first three comprise the Hepaticæ and the last three the Musci, as limited by the majority of botanical works; and it is still often convenient to employ the terms in this general sense.

THE MARCHANTIALES

The present order includes about half of the thalloid Bryophytes known from Connecticut, and most of the species are large and conspicuous. Two are normally aquatic, floating in ponds or slow streams; the others are all terrestrial, and even the aquatic species tend to become terrestrial through the drying up of the water in which they live. Except in the aquatic forms the thallus clings closely to the substratum,

sometimes so closely that it cannot be separated without injury. It develops two types of rhizoids, both of which represent simple outgrowths from cells. In one type the walls are thin throughout; in the other they bear scattered local thickenings in the form of short rods which project into the lumen. The rhizoids are all short-lived, and those of the first type simply anchor the plant to the substratum; those of the second type, however, by means of capillarity, play a certain part in the process of absorption. In addition to the rhizoids, the thallus often bears longitudinal rows of delicate scales on the lower surface. These are developed very early and arch up over the growing point, thus protecting it from injury.

The thallus is more or less differentiated, and always shows, at least in certain stages of development, a distinct epidermis, beneath which the photosynthetic tissue is situated. The latter consists of green cells loosely arranged with intercellular spaces containing air among them. In the higher forms these cells are in distinct air-chambers, which communicate with the outside air by means of pores in the epidermis. In the lower forms they simply line the intercellular spaces, and the communication with the outside air is often less definite. The Marchantiales are divided into two families, the Ricciaceæ and the Marchantiaceæ, which differ from each other most markedly in the structure of the sporophyte.

The Ricciaceæ include both aquatic and terrestrial species, and are usually smaller than the Marchantiaceæ. The terrestrial forms grow in old fields, along damp roadsides, and on the muddy borders of ponds. The thallus, which rarely attains a length of fifteen millimeters, forks repeatedly in one plane, thus giving rise to a characteristic rosette. All the New England species are annual, developing their sporophytes in the autumn. The aquatic Ricciaceæ are larger than the others, and rarely produce sporophytes, the tips of the thallus being able to survive the winter. When they become terrestrial, they sometimes assume an appearance very different from their normal aquatic state.

The archegonia in the Ricciaceæ are so deeply immersed in the thallus that only their necks protrude above the surface. In consequence of this fact the sporophytes begin their development beneath the surface, and they retain this position

until they are mature. The sporophyte is much simpler than in any of the other Bryophytes and consists of a spherical capsule only, which absorbs through its entire surface. The capsule contains nothing but spores, and these are at first enclosed by the capsule wall, consisting of a single layer of cells. As development advances, this wall gradually disappears, and the mature spores lie free within the calyptra. They are set free by the decay of the surrounding tissues of the gametophyte, and are dispersed largely through the agency of water.

The Marchantiaceæ are all terrestrial, some of them growing on shaded rocks or in their crevices and others on damp or wet earth. The thallus is more highly differentiated than in the Ricciaceæ, and in the larger species sometimes reaches a length of twenty centimeters or more and a width of ten millimeters. The branching is normally but not invariably by forking. The New England species are more or less perennial but some of them develop sporophytes during the first year.

Except in a few genera which do not occur in the eastern United States, the archegonia are borne on modified branches or outgrowths of the thallus known as *carpocephala*. These consist of two parts, an apical discoid or conical expansion and a basal cylindrical stalk. Sooner or later the stalk elongates and carries the expansion, to which it is attached in a peltate manner, high up above the surface of the thallus. As the sporophytes mature, they extend horizontally from the margin of the expanded portion or else hang downward from its lower surface. They are more complex than in the Ricciaceæ and not only develop a capsule with a persistent wall but also a foot and a short stalk, although the line of demarcation between the two latter organs is not always clearly defined. The spore cavity contains not only the spores but also a large number of peculiar bodies known as *elaters*, each of which consists of a long and slender cell with a thin cell wall, strengthened on the inside by one or more spiral bands of thickening. When the spores become mature, the stalk elongates slightly, the calyptra is ruptured, and the wall bursts, either by means of irregular valves extending backward from the apex, or else by a circular line, which leaves the basal

portion of the capsule wall in the form of a cup. As the spores and elaters become dry, the latter through their elasticity stretch out and separate the spores. In this way the contents of the capsule form a loose cottony mass, which can be easily carried away by the wind. In certain genera the gametophyte develops a special protective organ for the sporophyte outside the calyptra. This is usually in the form of a hollow tube or sheath open at the tip, and may be called a *pseudoperianth,* to distinguish it from a very similar organ found in many of the leafy Jungermanniales.

THE JUNGERMANNIALES

Both thalloid and leafy forms are here represented. All are characterized by a slight degree of cell differentiation and by a lack of intercellular spaces, even among the green cells. The rhizoids are all essentially alike and agree with the first type described for the Marchantiales. Their only function is that of anchorage, and to perform this more efficiently they frequently become lobed or branched at the extremity. In many of the genera absorption seems to be carried on by all the surface cells.

With the exception of a very few primitive types which are not known from New England, the sporophyte is practically uniform throughout the entire order. It consists of a distinct foot, a stalk, and a capsule, and it remains enclosed within the calyptra until the spores are mature. The stalk consists of strongly flattened cells arranged in longitudinal rows, and the capsule, as in the Marchantiaceæ, contains both spores and elaters. When the spores are ready to be disseminated, the stalk elongates rapidly through the lengthening of its individual cells and thus forces the capsule through the calyptra. The latter is thus irregularly ruptured but continues to enclose the base of the stalk. The capsule now raised on its stalk soon splits its wall, usually into four valves, the lines of dehiscence extending from the apex to or toward the base. The spores are scattered in much the same way as in the Marchantiaceæ, although the elaters sometimes play a more active part in their dispersal. The Jungermanniales are also divided into two families, the Metzgeriaceæ and the Jungermanniaceæ, the most

important differences in this case being in the gametophytes.

In most of the Metzgeriaceæ the gametophyte is a thallus, but a few of the genera show a more or less complete differentiation into stem and leaves. The plants are usually composed of parenchyma throughout, but a few thalloid species develop a very primitive conducting tissue composed of elongated cells with lignified walls. The archegonia are borne on the upper surface of the gametophyte or of a special branch, and do not directly terminate its growth. In many cases a protective structure is developed outside the calyptra, and this sometimes assumes the form of a pseudoperianth as in the Marchantiaceæ.

The Jungermanniaceæ are sometimes called Scale Mosses, the gametophyte being invariably a leafy stem. Most of the species are prostrate, and the plants show a distinct dorsiventrality, even when ascending or erect. The leaves are normally alternate and arranged in three ranks, two of which are turned toward the light and the third toward the substratum. The leaves of this third rank are called *underleaves*, and are usually much smaller than the others and different from them in form. Sometimes they are so much reduced in size that they can scarcely be demonstrated, and in a few genera they are absent altogether. The two ranks of large leaves usually spread out in such a way that the whole shoot acquires a strongly flattened appearance, very characteristic of the family as a whole.

The leaves as a rule exhibit no cell differentiation whatever, and are invariably destitute of midribs. They show, however, a great deal of variation in form and in the way in which they are attached to the stem. They are sometimes undivided, sometimes variously toothed, lobed, or deeply cleft; they are sometimes developed in one plane, sometimes variously folded; they are sometimes attached by a continuous line, sometimes by two lines which meet at an angle. In a few genera the leaves develop peculiar organs, known as *water sacs*, in which water may be temporarily retained. The branches sometimes show a differentiation into those which bear normal leaves and those which assume a flagelliform appearance, the leaves in the latter case being strongly reduced or even absent altogether. The flagelliform branches frequently perform the

function of holding the plant more firmly in place, and are confined to certain species and genera.

The archegonia are borne at the apices of stems or of special branches and stop their further elongation. The leaves and underleaves which develop in the immediate vicinity of the archegonia are more or less modified, and are designated *bracts* and *bracteoles* respectively. Taken together they constitute the *involucre*. This often surrounds the developing sporophyte and helps protect it. In the majority of the genera, however, the gametophyte develops a special protecting organ. This usually consists of a hollow tube, open at the top and enclosed by the involucre; and, since this tube is theoretically formed by the coalescence of modified leaves, it is called a *perianth*, although it is not homologous with the perianth in flowering plants. In a few cases the fertile branch takes on a peculiar growth as the result of fertilization, and forms a hollow cup around the sporophyte. This is known as a *perigynium*, and may be either pendent or erect. In the latter case the uppermost bracts and bracteoles are often carried up on the outside. In very rare instances the young sporophyte penetrates the tip of the fertile branch, which serves directly as a protecting organ without undergoing marked modifications. Under these circumstances the calyptra itself often fails to develop.

The Jungermanniales are about nine times as numerous in Connecticut as the Marchantiales. Less than one seventh of the recorded species are Metzgeriaceæ, the others being all Jungermanniaceæ. A few are more or less aquatic, either floating on the surface of the water or attached to submerged rocks or stones. A few others are to be found in bogs or swamps. The remainder grow on rocks, on banks, on earth, or on the trunks of trees, usually in damp and shaded localities. They vary greatly in size, a few being hardly perceptible to the naked eye, while others attain a length of ten centimeters or more. The sporophytes, with few exceptions, reach maturity in the spring.

THE ANTHOCEROTALES

The Anthocerotales are sometimes called Hornworts or Horned Liverworts, and embrace the single family Anthocerotaceæ. This includes only three recognized genera, two of which are represented in Connecticut. In spite of its small size, the order is of especial interest to the student of plant morphology and evolution, because it probably represents, more closely than any of the other existing Bryophytes, the ancestors of the Pteridophytes. The northern species are all annuals, and make their appearance in May or June in wet pastures, along roadsides, or on wet rocks. Each gametophyte has several sporophytes growing from it; they begin to develop late in the summer, and continue in many cases until the plants are killed by the frost.

The gametophyte is a thallus, sometimes bearing irregular and crispate outgrowths on the upper surface or along the margin, but never definitely divided into stem and leaves. The thallus branches by forking, but the forks are so close together that it soon assumes the form of a fleshy circular disc with many growing points scattered along the margin. It apparently absorbs throughout its entire surface, and is attached to the soil by means of thin-walled rhizoids, similar to those of the first type in the Marchantiales. The thallus shows but a slight degree of cell differentiation, but some of the species develop minute intercellular spaces, which, however, may contain slime as well as air. The green cells are characterized by the presence of a single large chloroplast in each. This is in the form of a plate with thin and irregular margins, lying close to the cell wall. Cells of this type are found nowhere else among the Bryophytes, and probably represent a primitive characteristic, indicative perhaps of a distant relationship with the green Algæ. In all the other orders each green cell contains a number of small, disc-like chloroplasts, and agrees in structure with the green cells of the higher plants. Taking it as a whole, the gametophyte in the Anthocerotales is even more primitive than in either the Ricciaceæ or Metzgeriaceæ. Even the archegonia, although showing essentially the same structure as in the other Bryophytes, are imbedded in the

thallus so that only the tip of the neck protrudes. For this reason no true calyptra is developed, the function of this organ being assumed by a tubular outgrowth of the gametophyte, which encloses the base of the sporophyte.

Although the gametophyte in the present order is so simple, the sporophyte shows a high degree of complexity when compared with the preceding groups. It consists of two principal parts, a spherical or flattened foot, and a long and slender capsule, tapering somewhat toward the apex. No true stalk is formed, the base of the capsule passing imperceptibly into an undifferentiated region composed of embryonic cells. These continue to give rise to new cells, which gradually become differentiated into the permanent tissues of the capsule. The presence of these embryonic cells enables the sporophyte to grow indefinitely, a power which no other sporophytes possess until the Pteridophytes are reached. On account of the basal position of the growing region, the apex of the capsule is the first part to mature, and all stages of development are to be observed in passing from the apex toward the base. The cross section is approximately circular, but sometimes two longitudinal grooves are formed, showing where the wall will eventually split. The latter is relatively much thicker than in the preceding orders, the spore cavity being distinctly smaller. In the higher forms the wall is bounded on the outside by a distinct epidermis, with stomata, and this encloses several layers of green cells separated by minute air spaces. The wall therefore represents a photosynthetic tissue, comparable to the mesophyll in the higher plants. In the lower forms the wall is less highly differentiated and no stomata are developed. The center of the capsule is occupied by a slender but more or less clearly defined *columella* composed of sterile cells, and the spore cavity is in the form of a hollow cylinder between the columella and the capsule wall. The cavity is continuous over the tip of the columella at the apex of the capsule. It contains both spores and elaters; but the latter are irregularly and poorly developed in northern species, and do not develop local thickenings in their walls. When the apex of the capsule is mature, the wall splits into two valves, the splits gradually extending downward as the development

proceeds. The valves, as they separate, soon become dry and black, and the columella appears like a fine hair projecting from the open capsule. The gametophyte covered over with sporophytes often presents the appearance of a tuft of fine grass.

The structure of the sporophyte in the Anthocerotales is so peculiar that Howe separated the order from the Hepaticæ and made of it a distinct subclass, to which he gave the name Anthocerotes. He therefore divided the Bryophytes into three subclasses; Hepaticæ, Anthocerotes, and Musci. In this procedure he is followed, provisionally at least, by Campbell, but European writers continue to use the term Hepaticæ in the old sense.

THE SPHAGNALES

The Sphagnales or Peat Mosses comprise the single genus Sphagnum. They are well represented in Connecticut, and include some of our largest and most conspicuous Bryophytes. The peat mosses are occasionally found on wet rocks or banks, but are most at home in bogs, where they sometimes grow submerged but more frequently rise above the surface of the water. In favorable localities they form dense and extensive colonies. Under these circumstances the stems are upright and afford one another mutual support. No rhizoids are developed except when the plants are very young. The branching is always monopodial, the branches arising in fascicles of from three to eight. The fascicles are numerous, and the branches appear densely crowded at the tips of the plants because the elongation of the stem is at first very slow. In older parts the fascicles become more separated. The branches are of three types:—spreading branches, which remain simple and are limited in growth; pendent branches, which also remain simple and limited in growth, but which grow downward close to the stem and form a sort of loose covering around it; erect branches, which are unlimited in growth and give rise to spreading and pendent branches of their own. These erect branches are only occasionally produced, and, since they repeat the stem in all respects, apparently arise by forking.

The leaves are arranged in five longitudinal rows, although

this fact is sometimes difficult to demonstrate. They are destitute of midribs, but show a remarkable differentiation into two kinds of cells: — green cells, which remain alive for a long time; and colorless cells, which soon lose their living contents and become empty. In the leaves of the spreading branches the green cells are united in such a way that they form a loose network, each mesh of which is filled with a single large colorless cell. The latter is characterized by a thin wall, usually with band-like thickenings on the inside which keep it from collapsing, and by holes or pores which place its cavity in direct communication with the outside. The stems and branches are usually covered over on the outside by a cortex composed of similar colorless cells; within this is a distinct zone of sclerenchyma enclosing a central pith. The tufted habit of the peat mosses, their upright stems covered with pendent branches, and their porous hyaline cells, account for the ease with which they suck up and retain water. The process is largely due to capillarity.

The archegonia are borne at the tips of branches, and limit their growth just as in the Jungermanniaceæ. The sporophyte consists of a spherical capsule and a broad foot with a deep constriction between them. No true stalk is developed. The calyptra persists until the spores are mature, and is then irregularly ruptured by the dehiscence of the capsule. The latter while still immature contains a large columella in the form of a hemisphere. This is covered over at the apex by the small spore cavity in much the same way as in the Anthocerotales, but the cavity contains spores only. The wall of the capsule is several cells thick, the outer layer forming a distinct epidermis. Some of the inner cells contain chloroplasts, but there are no intercellular spaces among them, and the epidermis develops no effective stomata, so that the wall can hardly serve as a very useful photosynthetic tissue. When the spores are mature, the upper part of the archegonial branch elongates rapidly, thus simulating a stalk, and the capsule opens by means of a circular split in the wall, which cuts off a cap-like lid. As the drying of the capsule proceeds, the pressure in the interior increases, until a sudden liberation takes place which shoots out the spores together with the

lid to a distance of ten centimeters or more. The ripening and scattering of the spores occurs in the summer months.

THE ANDREÆALES

The present order contains the single genus Andreæa, separated from the Bryales on account of the peculiar structure of the capsule. The species are all small, and grow in tufts on siliceous rocks, usually in mountainous regions. The gametophyte consists of an upright and sparingly branched stem bearing crowded leaves in the three-eighths arrangement. Except for the midrib, which occurs in certain species only, the leaves show no cell differentiation.

The sporophyte bears a certain resemblance to that of Sphagnum. It consists of an oval capsule and a well-developed foot, but no true stalk is formed. The calyptra is very delicate and is ruptured long before the spores are mature; sometimes it is carried up on the tip of the capsule, sometimes it remains at the base and the capsule protrudes through it, very much as in the Jungermanniaceæ. The capsule contains a definite columella, arched over by the spore cavity in the form of a hollow cylinder, and is bounded on the outside by a wall several cells thick. The wall has a distinct epidermis without stomata, and is probably not very efficient as a photosynthetic tissue, although some of its cells contain chloroplasts. When the spores are mature, the tip of the archegonial branch elongates rapidly, assuming the function of a stalk, and the wall of the capsule splits along four longitudinal lines. These do not extend, however, to the apex, but they are sufficient to expose the spores and to allow them to be scattered by the wind. The capsule usually reaches maturity in the spring or early summer.

THE BRYALES

The Bryales, or True Mosses, constitute the largest order of the Bryophytes, and include about two thirds of the Connecticut species. The gametophyte varies greatly in size, being sometimes only one millimeter long and sometimes attaining a length of ten centimeters or more. It always consists of a leafy shoot, the leaves being usually arranged in more than

three longitudinal rows. The leaves vary in form from linear to orbicular, and, although they are sometimes toothed or even ciliate on the margins, they are never deeply lobed or divided as in some of the Jungermanniaceæ. Except for the midrib, which may or may not be present, the leaves very rarely show any differentiation in their cells. In prostrate species the plants sometimes acquire a dorsi-ventral appearance, and a slight differentiation in the leaves is occasionally to be observed. These peculiarities, however, are never so clearly marked as in the Jungermanniaceæ, and there is little danger of confusing the True Mosses with the Scale Mosses. The branching in the Bryales is always of the monopodial type, and is often distinctly pinnate. In the lower forms the stem presents a simple and uniform structure, but in some of the higher genera it shows a distinct cell differentiation into storage, strengthening, and conducting tissues, and the same is sometimes true of the midribs of the leaves.

In the majority of cases the sporophyte shows a distinct foot, a firm stalk, which early becomes elongated, and a highly complex capsule. The calyptra at first keeps pace with the lengthening sporophyte but soon stops growing and becomes ruptured. In nearly every case the line of rupture is near the base, and the calyptra is carried up on the tip of the sporophyte. As the capsule gradually enlarges, the calyptra, which is now cut off from its source of food-supply, dries up and splits in one or more places, so that it frequently falls away long before the spores are mature. The spore cavity occupies a relatively small space in an immature capsule, and is in the form of a hollow cylinder open at both ends, differing in this respect from all the preceding Bryophytes. It encloses a massive columella, and is bounded by a thick wall, which, in most species, represents an efficient photosynthetic tissue. The outer cell layer of the wall forms an epidermis with stomata, the latter being usually restricted to the base of the capsule. The green cells are usually arranged in two more or less definite layers, one surrounding the spore cavity and the other lining the epidermis. These two layers are separated by a large air space in the form of a hollow cylinder. Stretching across the air space from one green layer to the other are

rows of green cells, which play a part in holding the central portion of the capsule in place. Of course the stomata afford a communication between the air space and the outside air.

As the spores mature, the photosynthetic tissue breaks down, the columella shrivels, and the spores eventually lie loose in an enlarged cavity, bounded by little more than the epidermal layer of the capsule wall. In a few of the simpler genera the capsule bursts irregularly at maturity. In the majority of cases, however, it splits by a circular line in the upper part, which cuts off an apical portion, or *lid,* from the capsule proper. Sometimes the region of splitting is marked by a row of modified epidermal cells, called an *annulus,* but this is not always developed. The walls of the annular cells have the power of absorbing water readily and swelling, thus forcing the lid to separate. After the lid has fallen away, the mouth of the capsule usually appears fringed with a circle of pointed *teeth* called a *peristome,* and in many genera two peristomes are developed, an inner and an outer. The inner peristome is always more delicate than the outer, and its divisions, when present, are called *segments,* instead of teeth. The segments are sometimes separated from one another by one or more delicate hair-like structures known as *cilia.* The peristome plays a peculiar part in the scattering of the spores; in moist weather the teeth come together and close the mouth of the capsule; in dry weather they separate and allow the wind to scatter the spores. Although the description just given will apply to the majority of cases, the structure of the capsule may be much simpler or even more complex than indicated. Taking the Bryales as a whole, the sporophyte shows the highest type of development to be found in the Bryophytes. It does not, however, show unlimited growth, the entire capsule maturing at the same time, and in this respect it is surpassed by the Anthocerotales.

The Bryales are divided by Brotherus into more than forty families, about half of which are represented in Connecticut. These are based on the general habit and structure of the gametophyte and on the peculiarities of the capsule, many of the most important characters being derived from the peristome. The species flourish best in moist and shaded

localities, and are often found in company with the Jungermanniales. Quite a number of them, however, are able to live in much drier localities, such as exposed rocks and sandy fields. Of the Connecticut species a few are annual but the majority are perennial. Most of them mature their spores in the fall or early winter, and the others in the spring or early summer. During the hot days of July, August, and September, many of the mosses become completely dried up, and their vegetative activities are interrupted. Even under favorable conditions for growth it is very unusual to find perfect capsules at this season of the year.

HISTORY OF BRYOLOGY IN CONNECTICUT

The first systematic collections of Bryophytes in Connecticut were made by Daniel C. Eaton, Professor of Botany in Yale University from 1864 until 1895, the year of his death. Professor Eaton was a member of the class of 1857, Yale College, and began his bryological studies while still an undergraduate. From the very outset he enjoyed the privilege of corresponding with W. S. Sullivant, of Columbus, Ohio, at that time the leading authority on North American Mosses and Hepatics, and this correspondence was continued until Sullivant's death in 1864. During this period many doubtful Connecticut specimens were sent for comment or determination, among them being a sterile Fontinalis collected near New Haven. This specimen is apparently the first Connecticut Bryophyte which is definitely mentioned in the literature. It was first referred to *F. biformis* Sulliv., and is listed under this name in the "Musci and Hepaticæ of the United States," originally written by Sullivant for the second edition of Gray's "Manual of Botany," published in 1856, but reprinted the same year as a separate work under the above title. *F. biformis* was based on Ohio specimens, and according to our present knowledge is restricted to the region of the Great Lakes. It was soon discovered therefore that the Connecticut material had been incorrectly determined. Sullivant hastened to call attention to this fact in the "Additions and Corrections" to his "Musci and Hepaticæ," which appear in the separate

edition, but are not included in the "Manual." The Connecticut Fontinalis is here transferred to *F. Novæ Angliæ* Sulliv., a species proposed as new and based on material from several stations in southern New England. Eight years afterward, in his "Icones Muscorum," Sullivant accredited to Connecticut a second species of Moss, *Grimmia Olneyi* Sulliv., originally described from Rhode Island material.

About the time of Sullivant's death, Professor Eaton began a correspondence with the late C. F. Austin, of Closter, New Jersey, who published many short papers on Bryophytes between 1863 and 1880. Austin was even more interested in the Hepaticæ than in the Mosses, and much of our present knowledge of this group of plants is based on his studies. In 1873 he issued his "Hepaticæ Boreali-Americanæ," the first set of exsiccatæ devoted exclusively to North American Hepatics. For this publication Professor Eaton supplied a portion of the material distributed under No. 115, as *Aneura pinnatifida* Nees, now known as *Riccardia sinuata* (Dicks.) Trevis., and this is apparently the first published reference to a Connecticut Hepatic, the specimens being recorded from near New Haven.

With the exception of these scattered notes nothing of importance seems to have been published on Connecticut Bryophytes until 1878, although a large collection was gradually being accumulated. In this year the Berzelius Society of the Sheffield Scientific School printed "A Catalogue of the Flowering Plants and Higher Cryptogams growing without cultivation within thirty miles of Yale College." This catalogue includes not only the Acrogens, or Pteridophytes, but also the Anogens, or Bryophytes, differing in this respect from the majority of local lists. The account of the Anogens, in which 170 Mosses and 54 Hepatics are enumerated, was prepared by Professor Eaton, and forms one of his most important contributions to the literature of bryology. The common and widely distributed species are listed by name only, but definite stations are given for the rarer species, and frequently the names of the collectors also are mentioned. Although Professor Eaton's own name appears but rarely, it is evident from his herbarium that he had found most of the species listed. Mr. J. A. Allen

is quoted for a number of the most interesting species, and Professor O. D. Allen, Mr. A. Barron, Mr. E. E. Brewster, Mr. W. T. Browne, Mr. N. Coleman, Dr. F. W. Hall, Dr. G. R. Kleeberger, Mr. F. N. Pease, Mr. R. Veitch, and Mr. A. H. Young are also mentioned as collectors. The Berzelius List has of course served as a basis for subsequent work on Connecticut Bryophytes, but no publication on the entire group, dealing with either the whole or a part of the state, has since appeared.

During the last thirty years, however, the Mosses and Hepatics have by no means been neglected, and many additional species have been detected within the state. Several of these were found by Professor Eaton himself, who continued his active interest in bryology throughout his life. Others were collected by Mr. J. A. Allen, including a number of rare and minute species which have not been rediscovered by later observers. Still others were found by more recent students of Professor Eaton, Mr. E. B. Harger, Professor W. A. Setchell, and Dr. C. B. Graves being among the number. During the last decade some of the most interesting additions have been made by Mrs. Josephine D. Lowe and Miss Annie Lorenz, and the authors of the present catalogue have also had a share in swelling the list of Connecticut Bryophytes.

In spite of this active collecting very little has been published on the true Mosses (Bryales) of Connecticut since the Berzelius List. A search through the scattered literature has brought to light less than a dozen species which are actually additions. Among the more important of these are the following: — *Thuidium Alleni* Aust., described from sterile specimens collected by Mr. J. A. Allen in Beaver Meadows, near New Haven; the rare *Claopodium pellucinerve* (Mitt.) Best, collected by Mrs. Lowe at Noroton in the town of Darien, and reported upon by Miss Harriet Wheeler; and *Anacamptodon splachnoides* Brid., first recorded by Mrs. Lowe from Burnside, in the town of East Hartford. As the present report shows, the number of known species is now 245. This does not include the two species of Andreæa discovered by Mr. J. A. Allen, which of course belong to a different natural order (Andreæales). For the "Musci Americæ Septentrionalis

Exsiccati," issued by Renauld and Cardot during the last fifteen years, Professor Eaton supplied a number of species from Connecticut, and these will be especially indicated in the list which follows.

The Peat Mosses (Sphagnales) and the Hepaticæ have received rather more attention than the True Mosses, and the majority of the additions which have been made in these two groups have already been recorded. In the Berzelius List only three species of Sphagnum are included. About 1890, however, Professor Eaton and the senior writer began to collect these interesting plants systematically, and to submit specimens to Dr. C. Warnstorf, then of Neuruppin, Germany, for determination. In this way the number of known species was markedly increased. In 1892 Warnstorf described as new, under the name *S. dasyphyllum,* a species from East Haven, which is still known from this locality only. In 1893 Professor Eaton published his "Check-List of North American Sphagna," indicating the geographical distribution of each species, so far as known at that time. Although Connecticut is included in several of the wider ranges, only five species are definitely recorded from the state, all of these being additions to the Berzelius Catalogue. The check-list was prepared for the convenience and guidance of Professor Eaton and Mr. Edwin Faxon, of Malden, Massachusetts, who were collecting sets of North American species for distribution. These sets were issued in 1896 by Dr. George F. Eaton, under the title "Sphagna Boreali-Americana Exsiccata," and constitute the only published exsiccatæ devoted exclusively to North American Peat Mosses. They include twenty-nine numbers from Connecticut, representing fourteen species. Three species from the state had already been distributed by Warnstorf, in the fourth series of his "Europaeische Torfmoose." In 1906 Andrews listed nineteen species of Sphagnum from Connecticut, and twelve additional species have been recently determined by Warnstorf from Connecticut specimens, so that thirty-one species in all are now known.

Since the publication of the Berzelius List the number of known species of Hepaticæ within the state has been almost doubled. The seven following species, occurring in Con-

necticut, have been described as new: *Calypogeia tenuis* (Aust.) Evans, *Diplophylleia apiculata* Evans, *Frullania Brittoniæ* Evans, *Jungermannia Novæ-Cæsareæ* Evans, *Lepidozia sphagnicola* Evans, *L. sylvatica* Evans, and *Plagiochila Sullivantii* Gottsche. Unfortunately two of these have since been reduced to synonymy, *Jungermannia Novæ-Cæsareæ* being now considered a form of *Lophozia marchica* (Nees) Steph., and *Lepidozia sphagnicola* being included under *L. setacea* (Web.) Mitt. Many other additions to the hepatic flora of the state have been recorded in a series of "Notes on New England Hepaticæ," and in a "Preliminary List," both published by the senior writer in Rhodora. It should be noted, however, that the earliest references to *Riccia arvensis* Aust. and *Mylia anomala* (Hook.) S. F. Gray are to be found in the writings of Professor L. M. Underwood, and that Dr. M. A. Howe was the first to report *Porella rivularis* (Nees) Trevis. and *Anthoceros punctatus* L. Fifteen species of Connecticut Hepaticæ and Anthocerotes have been distributed in Underwood and Cook's "Hepaticæ Americanæ," all of which are indicated below. Several other species are included in the first two decades of the "American Hepaticæ," recently issued by Miss Caroline C. Haynes.

The bryophytic flora of Connecticut is perhaps as well known as that of any equal area in North America, but the region has not yet been so intensively studied as certain parts of Europe. This is due partly to the fact that here, as in other groups, common species have been largely neglected by collectors, and are therefore less fully represented in our herbaria than some of the rarer and more local species. The attempt has been made of late to collect even the commonest species more systematically, but much still remains to be done, and many parts of the state still remain to be explored before our knowledge can be considered at all complete. This is especially true of the towns in the eastern and northeastern counties.

DISTRIBUTION OF THE BRYOPHYTES IN CONNECTICUT ACCORDING TO ENVIRONMENT

Even to the casual observer it is evident that the character of the vegetation which clothes the surface of the earth varies greatly under different conditions. There is a marked contrast, for example, between the impenetrable tangle of a tropical jungle with its wide diversity of species, and the northern spruce forests which are relatively open and are made up of comparatively few species. The vegetation at the summit of Mount Washington is scant and limited to shrubby and herbaceous plants, while the valleys but a few thousand feet below are heavily wooded. Ordinary land plants differ strikingly in appearance from seaweeds and other submerged aquatics.

These are perhaps extreme illustrations, but innumerable examples of this adaptation to environments which are less diverse may be seen everywhere. The vegetation in an open field presents a decided contrast to that of a pine grove but a few hundred yards distant, while the flora in a bog is totally different from that in a meadow.

It may be stated as a general rule that every plant is best adapted to a peculiar environment, and that for every species there are certain more or less well defined limits outside of which it cannot exist. What is true of the higher plants applies even more forcibly to the Mosses and Hepatics, for, as Lesquereux remarks, " these humble and apparently useless beings have their geological and lithological preferences far better marked than any other kind of vegetable."*

The factors which produce this environment and determine these limits are numerous, but the following are the most important:

I. Latitude.
II. Altitude.
III. Character of the substratum.
IV. Intensity of the light.
V. Water supply.

*Quoted by Mohr: Plant Life of Alabama. Contr. U. S. Nat. Herb., 6: 292. 1901.

In treating an area such as the continent of North America, where all gradations from an arctic to a tropical climate are encountered, the first of these factors bears an important relationship to the character of the vegetation. Many Bryophytes are exclusively northern in their range, while others are restricted to tropical regions. A comparatively small number are found from the arctic regions to the equator. In considering the Mosses and Hepatics of Connecticut, however, latitude is of relatively little importance.

In the same way the second factor may be disregarded, since nowhere in the state are the differences in altitude sufficient to produce any appreciable climatic effect.

To a certain extent the nature of the substratum determines the character of the bryophytic flora, and various societies might be defined from this point of view, as, for example, the following: — species growing on rocks; species growing on soil; species growing on living trees; species growing on dead trees, rotten wood, etc. Yet the boundaries between such societies are often vague, since many species flourish equally well on a variety of substrata.

Except in the northwestern part of Connecticut, it is probable that the actual chemical composition of the rocks and soil has very little direct effect upon the character of the vegetation. Indirectly, however, the structure of the underlying rocks is an important factor, as may be seen by considering the geography of the state.

"The state of Connecticut is naturally divided into three areas, the Eastern Highland, the Western Highland, and the Central Lowland. The Central Lowland may be further divided into a central range of hills and an eastern and a western valley."* The sedimentaries in the valleys with the overlying drift tend to produce a more or less level surface, which is interrupted only by a few ravines and by occasional bogs. For the most part this area is under cultivation, but, although favorable for agriculture, it does not present conditions conducive to an extensive bryophytic flora. In marked contrast to this uniform area are the trap ridges which rise

*Rice and Gregory: Manual of the Geology of Connecticut. Conn. Geol. & Nat. Hist. Surv., Bull. 6, p. 17. 1906.

abruptly to a height of several hundred feet above the surrounding plain. Geologically, these ridges are a part of the Central Lowland. From an ecological standpoint, however, they conform with the Highlands. The Eastern and Western Highlands are made up for the most part of a complex series of crystalline rocks — gneisses, schists, and granites. The forces of erosion, acting on these, have produced an uneven and rugged topography. Like the trap ridges, this region is well wooded, and, while on the whole unsuitable for agriculture, it exhibits a diversity of conditions, and is characterized by a rich bryophytic flora.

From a bryological standpoint, the most interesting isolated formation in the state is the Stockbridge limestone, which covers the greater part of the towns of Salisbury and Canaan, extending southward through the Housatonic Valley more or less continuously to Ridgefield. A few species grow in this region which have been collected nowhere else in the state, viz.:

Lophozia Muelleri	*Amblystegiella confervoides*
Barbula fallax	*Amblystegium noterophilum*
Thuidium abietinum	*Cratoneuron filicinum*

Other species occur here which, although characteristic of limestone regions, are found in other localities growing on serpentine or other rocks, e. g.:

Preissia quadrata	*Scœlania glaucescens*
Frullania riparia	*Hymenostylium curvirostre*
Fissidens cristatus	*Myurella gracilis*

Chrysohypnum stellatum

The distribution of the Bryophytes is somewhat restricted and frequently the habit of the individual plant greatly modified by differences of light and shade. In a general way two rather broadly defined classes may be recognized: light-loving, and shade-loving Bryophytes. In the first of these classes may be placed such species as —

Riccia arvensis	*Tortula papillosa*
Frullania eboracensis	*Bryum argenteum*
Anthoceros levis	*Thelia Lescurii*

In the latter and by far the larger group should be placed such species as —

Metzgeria conjugata	*Leucobryum glaucum*
Plagiochila asplenioides	*Stereodon curvifolius*
Bazzania trilobata	*Thamnium alleghaniense*

Yet, however much the preceding factors affect the distribution of the Mosses and Hepatics, the problem is eventually reduced to another factor, viz., the amount, nature and continuity of the water supply. Many species grow only on dry, exposed rocks, while to others the presence of free surface-water is essential. Some of the latter grow only in standing or slowly moving water, others are always found in rapidly flowing streams. But the majority of the Bryophytes thrive in an environment where they are not subjected to prolonged periods of drought or inundation.

Taking the requirements with regard to water as a basis, Warming* recognizes four groups of plants:

I. XEROPHYTES: plants which grow on rocks, or on soil which contains, at least during the greater part of the year, a very small amount of water.

II. MESOPHYTES: plants adapted to soil containing a moderate amount of water.

III. HYDROPHYTES: plants which are completely or partly submerged, or which grow in very wet soil.

IV. HALOPHYTES: plants which are adapted to a saline soil.

Considerable attention has been given to the ecological relationships of the higher plants, and several authors have attempted to classify the Bryophytes with respect to their habitats. Warnstorf†, however, was the first to adapt Warming's classification to the group.

Among the Bryophytes there are no true halophytes. Following Warming's classification the other three groups are

* Warming: Lehrbuch der ökologischen Pflanzengeographie. Second German edition, 1902, pp. 121, 122.

† Warnstorf: Kryptogamenflora der Mark Brandenburg, 1: 20-25, 1903.

well defined, and of these groups the species given below may be considered typical members:—

XEROPHYTES.

1. Plants growing on exposed rocks with little or no earth covering — trap ledges, stone walls, bowlders, etc.

Frullania Asagrayana — *Grimmia Olneyi*
Andreæa Rothii — *Ulota Hutchinsiæ*
Hedwigia albicans

2 Plants growing on living trees in the open or in the woods.

Frullania eboracensis — *Drummondia clavellata*
Orthotrichum ohioense — *Leucodon julaceus*
Thelia hirtella

3. Plants growing on earth, or on rocks with a thin earth covering in fields and along roadsides or in dry woods.

Nardia crenulata — *Pogonatum tenue*
Diplophylleia apiculata — *Thelia Lescurii*
Physcomitrium turbinatum — *Rhynchostegium serrulatum*

MESOPHYTES — for the most part shade-loving plants, but frequently found in the open on the borders of brooks, in meadows, etc.

1. Plants growing on the surface or in the crevices of cliffs and steep rocks.

Reboulia hemisphærica — *Rhabdoweisia denticulata*
Leucolejeunea clypeata — *Didymodon rubellus*
Hymenostylium curvirostre

2. Plants growing on soil or humus, on flat earth-covered rocks, on the roots and at the base of trees, or on decaying logs and stumps in wet woods.

Lophocolea heterophylla — *Polytrichum ohioense*
Ptilidium pulcherrimum — *Ptilium Crista-Castrensis*
Timmia cucullata — *Climacium americanum*

HYDROPHYTES.

1. Plants growing in more or less wooded swamps.

a. On the ground.

Trichocolea tomentella	*Brachythecium Novæ-Angliæ*
Elodium paludosum	*Calliergon cordifolium*

b. On sticks and bushes.

Dichelyma capillaceum

2. Plants growing on wet or dripping rocks in streams and ravines.

Riccardia sinuata	*Eurynchium rusciforme*
Jubula pennsylvanica	*Amblystegium Lescurii*

Thamnium alleghaniense

3. Plants growing in open bogs, especially peat bogs, and usually forming compact masses of vegetation.

Lepidozia setacea	*Sphagnum* (most species)
Scapania irrigua	*Acrocladium cuspidatum*

Drepanocladus aduncus

4. Plants submerged or floating in the water.

Ricciella fluitans	*Sphagnum obesum*
Ricciocarpus natans	*Octodiceras Julianum*
Porella pinnata	*Fontinalis Lescurii*

ECONOMIC VALUE OF THE BRYOPHYTES

Although the majority of the Bryophytes are of small size when compared with the seed-bearing plants, they often form dense and extensive colonies and thus constitute a conspicuous feature of the landscape. This is especially true in mountainous and northern regions, where woody plants are stunted in growth and occur more sparingly than under more favorable climatic conditions. Even in Connecticut, however, where the higher plants exhibit a vigorous development, the Sphagnales and certain of the other Bryophytes are often abundant enough to attract the attention of the ordinary observer.

On account of the tufted habit of so many species and the power which they possess of absorbing and retaining water,

they exercise a marked influence on both agriculture and forestry. Their importance from this point of view, which is only beginning to be appreciated, has been clearly demonstrated by Georg Roth.* According to this author, the mosses tend to diminish floods and to reduce the gullying of the soil, at the same time preserving its porosity. They are also of value in adding to the richness of the soil through their decay and in assisting in the disintegration of rocks. The Sphagnales, through their peculiar place and habit of growth, are active in converting lakes and ponds into bogs, which afford a foothold for higher plants and eventually yield a serviceable soil.

From a commercial standpoint the Sphagnales are by far the most important of the Bryophytes. In countries where they are abundant they yield the best quality of peat. This is produced by the death of the older portions of the Peat Mosses, the living stems continuing their upward growth indefinitely. As the dead layer becomes thicker, it becomes more and more compressed, and finally forms a firm and compact mass at the bottom of the bog. This mass is cut into bricks, which are dried and constitute the peat of commerce. Of course the chief use of peat as a fuel is for domestic purposes. In certain localities, however, it is charred and then used in steel and copper mills, where its purity from foreign substances and its power to produce an intense heat make it especially effective.

The Peat Mosses are also useful as a packing substance. In a dry form they are sometimes employed as a filling for pillows and mattresses, especially those used by invalids. They may also be wrapped around steam pipes or packed in the walls of houses, where they act as a non-conducting substance. In a moist form they are being more and more used by gardeners and florists as a packing material for vegetables and other cultivated plants. Owing to their great power of absorption, Peat Mosses are sometimes substituted for straw in stables, and they have also been employed to a limited extent in surgical dressings. The same peculiarity makes it possible to use them for lamp-wicks in the far north.

* Die europäischen Laubmoose. 1: 62-77. Leipzig, 1905.

A few of the Bryales constitute a secondary source of peat, and others are used as a packing material but to much less extent than the Peat Mosses. Some of the large species, when dried without pressure and dyed, form a component part of decorative wreaths and cords, which are made use of more especially by milliners. The stiff and wiry stems of *Polytrichum commune* have also been employed instead of bristles in the manufacture of brushes. Among the Marchantiales the only species which have ever been used for practical purposes are *Marchantia polymorpha* and *Conocephalum conicum*. These were formerly prescribed in affections of the liver, but it is doubtful if they possess any true therapeutic properties. Except for the fact that a few of the Jungermanniales have been used in the tropics as a packing material for living plants, the remaining orders of the Bryophytes have been put to no practical uses whatever.

CATALOGUE OF CONNECTICUT BRYOPHYTES

The following catalogue records the distribution of the Bryophytes of Connecticut, so far as known to the writers. Under each species the characteristic environment and often the time of fruiting are given, together with the known localities for the state. These are arranged alphabetically by towns under the counties, the latter being given in the following order: Litchfield, Hartford, Tolland, Windham, Fairfield, New Haven, Middlesex, New London. The names of the collectors are also noted, but the only date mentioned is that of the earliest known collection. In case two or more persons have found the same species in the same township, the one who collected it first is the only one alluded to. The local distribution is followed by brief notes regarding the known distribution in North America and in other parts of the world. For the sake of completeness attention is also called to Connecticut specimens which have been distributed in exsiccatæ and to references in the scattered literature of bryology which relate directly to Connecticut plants. The numbers following the authors' names in these references correspond with the list and page numbers in the bibliography.

The genera, where represented by more than a single species, are supplied with artificial keys to the species, and the orders or families are supplied with similar keys to the genera. The arrangement followed is in most respects like that given in Engler & Prantl's "Die natürlichen Pflanzenfamilien." Since, however, the treatment of the Bryales in this work is still incomplete, the hypnoid Mosses are largely arranged according to Warnstorf in the second volume of the "Kryptogamenflora der Mark Brandenburg." Warnstorf is also followed in the position of the Polytrichaceæ and allied families. These apparently represent the most highly developed members of the Bryophytes, and it is therefore most logical to place them at the conclusion of the series.

[Subclass Hepaticæ]

ORDER MARCHANTIALES

FAMILY RICCIACEÆ

1. Terrestrial; green cells in rows at right angles to the upper surface of the thallus, enclosing air spaces in the form of narrow canals; epidermis without pores....**Riccia**
   Terrestrial or aquatic; green cells in layers one cell thick, separating the irregular air spaces from one another.. 2
2. Epidermis without pores, sometimes becoming irregularly ruptured with age................................**Ricciella**
   Epidermis with distinct pores, not becoming ruptured with age ....**Ricciocarpus**

Riccia (Mich.) L.

Riccia arvensis Aust.

Cultivated fields and margins of ponds. Autumn. HARTFORD: Hartford, *Harger*. NEW HAVEN: Orange (1892), *Evans*. MIDDLESEX: Middlefield, *Evans*.

Ontario to Maryland.

EXSIC. Miss Haynes, Amer. Hep. No. 2.

REF. Evans, **28**, 170. Underwood, **74**, 278; **76**, 4.

Ricciella A. Br.

1. Capsules rupturing on the upper surface of the thallus; epidermis soon breaking down and leaving the sponge-like green tissue exposed....................**R. crystallina**
   Capsules rupturing on the lower surface of the thallus 2

2. Aquatic, or rooting on wet mud; epidermis persistent **R. fluitans**
Terrestrial; epidermis eventually breaking down **R. Sullivantii**

Ricciella crystallina. (L.) Warnst. *Riccia crystallina* L.

On mud, often growing on margins of ponds. Autumn. NEW HAVEN: Oxford (1898), *Harger.*

Connecticut west to Oregon and south to the West Indies and California; Europe; Asia.

REF. Evans, **26**, 207; **28**, 170.

Ricciella fluitans (L.) A. Br. *Riccia fluitans* L.

Floating in ponds or slow streams or rooting in mud. Autumn. LITCHFIELD: Goshen, *Underwood.* HARTFORD: Berlin, *Coleman;* Southington, *Andrews.* WINDHAM: Plainfield, *Sheldon.* FAIRFIELD: Bethel, *Underwood;* Danbury, *Nichols.* NEW HAVEN: Branford, *Evans;* Hamden, *O. D. Allen;* New Haven (1868), *Eaton;* North Branford, *Evans;* Southbury, *Harger.*

New England and Ontario, west to British Columbia and south into tropical America; Europe; Asia; Africa; New Zealand.

EXSIC. Underwood & Cook, Hep. Amer. No. 11 (as *Riccia fluitans*).

REF. Eaton, **15**, 68. Evans, **28**, 170.

Ricciella Sullivantii (Aust.) Evans. *Riccia Sullivantii* Aust.

Cultivated fields and margins of ponds. Autumn. HARTFORD: East Hartford, *Weatherby;* Hartford, *Harger.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: East Haven, *Evans;* Milford, *Miss Lorenz;* New Haven, *O. D. Allen;* Orange (1876), *Eaton;* Oxford, *Harger.* MIDDLESEX: Middlefield, *Evans.*

New England to Virginia and west to Ohio.

REF. Eaton, **15**, 68. Evans, **28**, 170; **33**, 56.

Ricciocarpus Corda

Ricciocarpus natans (L.) Corda. *Riccia natans* L.

Floating in ponds or growing on mud. May and June.

LITCHFIELD: Salisbury, *Mrs. Phelps.* HARTFORD: New Britain, *Shepard.* FAIRFIELD: Fairfield and Stratford, *Eames.* NEW HAVEN: East Haven, *J. A. Allen;* Milford, *Eames;* New Haven (1875), *Eaton;* Oxford, *Harger.* MIDDLESEX: Clinton, *Miss Marion Clark.*

New England west to British Columbia and south to Mexico; Brazil; Europe; Asia; Australia.

REF. Eaton **15**, 68. Evans, **28**, 170.

FAMILY MARCHANTIACEÆ

1 Air chambers in several layers, separated from one another by plates of green cells.............................. 2
Air chambers in a single layer, the green cells arranged in simple or branched rows arising from the floors of the chambers 4

2. Sporophytes destitute of distinct pseudoperianths........ 3
Sporophytes each surrounded by a distinct pseudoperianth, consisting of a thin membrane divided longitudinally into eight segments.............................**Asterella**

3. Ventral scales of thallus purple, scarcely projecting beyond the margin; capsule only partially filling the involucral cavity ....**Reboulia**
Ventral scales of thallus soon becoming bleached, extending far beyond the margin, and usually forming a dense tuft at the apex; capsule completely filling the involucral cavity ....**Grimaldia**

4. Pores in epidermis of thallus simple, each surrounded by a single layer of cells.............................. 5
Pores in epidermis compound or barrel-shaped, each surrounded by cells arranged in several tiers............ 6

5. Outlines of air chambers distinct to the naked eye; gemmæ none; plant native ....**Conocephalum**
Outlines of air chambers indistinct to the naked eye; gemmæ abundant, produced in crescentic receptacles; plant introduced into greenhouses................**Lunularia**

6. Gemmæ none; carpocephala with indistinct flat rays **Preissia**
Gemmæ usually abundant, produced in cup-shaped receptacles; carpocephala with distinct terete rays **Marchantia**

Reboulia Raddi

Reboulia hemisphærica (L.) Raddi. *Asterella hemisphærica* Beauv.

On shaded banks and in crevices of rocks. May and June.

LITCHFIELD: New Milford, *Evans.* HARTFORD: Windsor, *Evans.* FAIRFIELD: Redding, *Miss Haynes;* Sherman, *Evans.* NEW HAVEN: Branford, *Livingston;* Hamden and New Haven (1873), *Eaton;* Oxford, *Harger;* Woodbridge, *J. A. Allen.* MIDDLESEX: Middletown, *Evans.* NEW LONDON: Montville, *Lumsden.*

New England west to British Columbia and south to Mexico; Europe; Asia; Africa; South America; Australia.

REF. Eaton, **15**, 68. Evans, **28**, 170.

Grimaldia Raddi

Grimaldia fragrans (Balb.) Corda. *Grimaldia barbifrons* Bisch.

Thin soil on rocks, often in exposed localities. May and June. LITCHFIELD: Salisbury, *Evans.* HARTFORD: Farmington, *Miss Lorenz;* Hartford, *H. S. Clark;* Simsbury, *Miss Lorenz.* FAIRFIELD: Monroe, *Miss Lorenz.* NEW HAVEN: New Haven (1856), *Eaton;* North Haven, *Evans;* Orange, *Harger;* Woodbridge, *Evans.*

Quebec and New England west to Alaska and south to New Mexico and Texas; Europe; northern Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 121.

REF. Eaton, **15**, 68. Evans, **28**, 170. Underwood, **71**, 35; **75**, 68.

Asterella Beauv.

Asterella tenella (L.) Beauv. *Fimbriaria tenella* Nees.

Shaded banks and thin soil on rocks. May and June. LITCHFIELD: New Milford, *Evans.* TOLLAND: Andover, *Weatherby;* Bolton, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Cheshire, *Evans;* East Haven, *J. A. Allen;* Hamden (1868), *Eaton;* Oxford, *Harger;* Woodbridge, *Hall.* MIDDLESEX: Middletown, *Evans.*

New England west to Missouri and south to Georgia.

REF. Eaton, **15**, 68. Evans, **28**, 170.

Conocephalum Wigg.

Conocephalum conicum (L.) Dumort.

On shaded banks and rocks, especially along streams. April and May. LITCHFIELD: Goshen, *Underwood;* New Milford

and Salisbury, *Evans*. HARTFORD: Southington, *Chamberlain;* Windsor, *W. E. Britton*. TOLLAND: Bolton and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley;* Plainfield, *Sheldon;* Windham, *Nichols*. FAIRFIELD: Danbury, *Nichols;* Greenwich, *Miss Haynes;* Huntington, *Evans;* Redding, *Underwood;* Sherman, *Evans*. NEW HAVEN: Cheshire, *Harger;* Hamden and New Haven (1856), *Eaton;* North Haven and Woodbridge, *Evans*. MIDDLESEX: Chester, *Nichols*. NEW LONDON: Ledyard, *Nichols*.

Newfoundland west to Alaska and south to Florida and Nebraska; Europe; Asia.

REF. Eaton, **15**, 69. Evans, **28**, 170. Underwood, **75**, 67.

Preissia Corda

Preissia quadrata (Scop.) Nees.

On rocks and banks, more abundant in limestone districts. May and June. LITCHFIELD: New Milford and Salisbury (1892), *Evans*. HARTFORD: Windsor, *Evans*. TOLLAND: Bolton, *Nichols*. FAIRFIELD: Sherman, *Evans*. NEW HAVEN: North Haven, *Nichols;* Orange, *Evans*.

Greenland to Alaska and south to Mexico; Europe; Asia.

REF. Evans, **28**, 170.

Lunularia (Mich.) Adans.

Lunularia cruciata (L.) Dumort. *L. vulgaris* Raddi.

Introduced into greenhouses, and reproducing (in the eastern United States) solely by means of gemmæ. NEW HAVEN: New Haven (1868), *Eaton*. Doubtless widely distributed throughout the state.

New England west to California and south to the West Indies; native in the Mediterranean regions of Europe, Asia, and Africa; Chile; Australia.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Marchantia (March. f.) L.

Marchantia polymorpha L.

On banks and rocks, in swamps, gardens, and cultivated fields. June-August. LITCHFIELD: Goshen, *Underwood;*

New Milford, *Evans*. HARTFORD: Windsor, *Evans*. TOLLAND: Bolton, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Sherman, *Evans*. NEW HAVEN: Branford, *Hall;* East Haven, *Harger;* New Haven (1856), *Eaton;* Orange, *Evans;* Oxford, *Harger;* Woodbridge, *O. D. Allen*.

Greenland to Alaska, south to Florida and the West Indies; Europe; Asia.

REF. Eaton, **15**, 69. Evans, **28**, 170. Underwood, **75**, 69.

ORDER JUNGERMANNIALES

FAMILY METZGERIACEÆ

1. Gametophyte a thallus with no indication of leaves; capsule splitting longitudinally at maturity into four valves 2
   Gametophyte more or less clearly differentiated into stem and leaves 5
2. Thallus composed of parenchyma throughout.......... 3
   Thallus with a median strand of narrow elongated cells 4
3. Branches lateral: capsule oval..........**Riccardia**
   Branching produced by forking; capsule spherical....**Pellia**
4. Thallus repeatedly forking, bearing cilia on the margin; antheridia and archegonia borne on short ventral branches ....**Metzgeria**
   Thallus simple or with scattered ventral branches, margin entire; antheridia and archegonia borne on dorsal surface ....**Pallavicinia**
5. Leaves in the form of marginal crenulate scallops; rhizoids colorless; capsule splitting longitudinally at maturity into four valves..........**Blasia**
   Leaves distinct; rhizoids purple; capsule splitting irregularly at maturity..........**Fossombronia**

Riccardia S. F. Gray

1. Thallus mostly 4-10 mm. broad, sparingly branched **R. pinguis**
   Thallus mostly 1-2 mm. broad, copiously branched...... 2
2. Thallus pinnate or bipinnate.......... 3
   Thallus palmate or irregularly branched.......... 4
3. Ultimate branches distinctly bordered by 2 or 3 rows of cells ....**R. multifida**
   Ultimate branches indistinctly bordered by one row of cells ....**R. sinuata**

4. Cortical cells averaging 0.07 × 0.04 mm; gemmæ rare **R. latifrons**
Cortical cells averaging 0.04 × 0.025 mm; gemmæ two-celled, often abundant........................**R. palmata**

Riccardia pinguis (L.) S. F. Gray. *Aneura sessilis* Spreng.

In swamps. April-June. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Hartford, *A. H. Graves*. NEW HAVEN: East Haven (1874), *Hall;* Orange, *Evans*. MIDDLESEX: Cromwell, *Evans*.

Greenland to Alaska, and south to the West Indies, Mexico, and Brazil; Europe; Asia; Africa; Australia.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Riccardia multifida (L.) S. F. Gray. *Aneura multifida* Dumort.

In swamps and on wet rocks. May and June. LITCHFIELD: Salisbury, *Evans*. FAIRFIELD: Redding, *Evans*. NEW HAVEN: Orange (1876) and Woodbridge, *J. A. Allen*.

Newfoundland and Nova Scotia, south to Virginia; British Columbia to California; Europe; Asia.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Riccardia sinuata (Dicks.) Trevis. *Aneura pinnatifida* Nees, in part.

On dripping rocks. April and May. NEW HAVEN: Hamden (1855), *Eaton;* Woodbridge, *J. A. Allen*.

New England south to New Jersey; also in British Columbia; Europe; Asia. A rare species, the range of which is very incompletely known.

EXSIC. Austin, Hep. Bor.-Amer. No. 115, in part (as *Aneura pinnatifida*). Miss Haynes, Amer. Hep. No. 36.

REF. Eaton, **15**, 69. Evans, **28**, 170. Underwood, **71**, 55; **72**, 726.

Riccardia latifrons Lindb.

On rotten logs. May-August. LITCHFIELD: Salisbury, *Evans*. TOLLAND: Bolton and Stafford, *Nichols*. NEW HAVEN: Cheshire, *Evans;* Woodbridge (1879), *J. A. Allen*.

Newfoundland west to Alaska and south to New England and New York; Europe; Asia.

REF. Evans, **28**, 170.

Riccardia palmata (Hedw.) Carruth.

On rotten logs. May and June. NEW HAVEN: Cheshire (1887), *Setchell.*

Nova Scotia west to Alaska and south to New England, New York, and California; Europe; Asia.

REF. Evans, **28**, 170.

Metzgeria Raddi

Metzgeria conjugata Lindb. *M. furcata* of some authors.

On shaded rocks and trunks of trees. May and June. LITCHFIELD: New Milford, *Evans.* WINDHAM: Canterbury, *Mrs. Hadley;* Killingly, *Rounds.* FAIRFIELD: Danbury, *Eaton;* Redding, *Miss Haynes.* NEW HAVEN: East Haven, *Eaton;* Hamden, *J. A. Allen;* Meriden, *Evans;* New Haven (1856) and Orange, *Eaton;* Seymour, *Evans.* MIDDLESEX: Killingworth, *Evans.* NEW LONDON: Norwich, *Setchell.*

New England west to Alaska and south to Argentina and Chile; Europe; Asia; Africa.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Pallavicinia S. F. Gray

Pallavicinia Lyellii (Hook.) S. F. Gray. *Steetzia Lyellii* Lehm.

In swamps and bogs, sometimes aquatic. April-June. LITCHFIELD: Norfolk, *Miss Lorenz.* HARTFORD: East Hartford, *Miss Lorenz;* Windsor, *Evans.* TOLLAND: Stafford and Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Bethany and East Haven, *Evans;* Hamden, *J. A. Allen;* Madison and Middlebury, *Evans;* New Haven (1877), *J. A. Allen;* North Haven, *Evans;* Oxford, *Harger.* MIDDLESEX: Chester, *Nichols.* NEW LONDON: Groton, Preston, and Waterford, *C. B. Graves.*

Newfoundland west to Ontario and south into tropical America; Europe; Asia; Africa; New Zealand.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Pellia Raddi

Pellia epiphylla (L.) Corda.

On shaded banks and damp rocks. April and May. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Mrs. Phelps.* HARTFORD: Windsor, *W. E. Britton.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Huntington, *Evans;* Redding, *Miss Haynes.* NEW HAVEN: Bethany, *Evans;* Hamden, *J. A. Allen;* Madison, *Nichols;* New Haven, *Evans;* Orange (1873), *Hall;* Woodbridge, *Eaton.* MIDDLESEX: Chester, *Nichols.*

Labrador to Alaska and south to New England, New York, and Indiana; Europe; Asia.

EXSIC. Miss Haynes, Amer. Hep. No. 35.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Blasia L.

Blasia pusilla L.

On damp banks and rocks. April and May. LITCHFIELD: Cornwall, *Underwood;* Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Huntington, *Evans.* NEW HAVEN: Derby, *J. A. Allen;* Hamden (1875), *Hall.*

Nova Scotia west to Alaska and south to Virginia, New Mexico, and California; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 5.

REF. Eaton, **15**, 69. Evans, **28**, 170.

Fossombronia Raddi

1. Annual; capsules mature in autumn...................... 2
   Perennial; capsules mature in May and June........**F. salina**
2. Spores with subparallel and rarely anastomosing ridges **F. Wondraczekii**
   Spores with anastomosing ridges forming a network **F. foveolata**

Fossombronia salina Lindb.

On earth in wet pastures and swamps. May and June. NEW HAVEN: East Haven, *Evans;* Hamden (1879) and Orange, *J. A. Allen.*

Connecticut south to Florida and the West Indies and west to Tennessee and Arkansas.

REF. Evans, **24**, 10; **28**, 170.

Fossombronia Wondraczekii (Corda) Dumort.

In damp fields and along roadsides. Sept.-Nov. NEW HAVEN: Oxford (1894), *Harger*. MIDDLESEX: Portland, *Johnson*.

New England west to Indiana and south to Maryland; Europe; Asia.

REF. Evans, **24**, 10; **28**, 170.

Fossombronia foveolata Lindb.

In damp fields and along roadsides. Sept.-Nov. NEW HAVEN: Branford, Cheshire, and Hamden, *Evans;* Milford, *Miss Lorenz;* New Haven, *Evans;* Orange (1879), *J. A. Allen*. MIDDLESEX: Portland, *Evans*.

Quebec and Ontario west to British Columbia and south to New Jersey and Delaware; Europe.

REF. Evans, **28**, 170.

FAMILY JUNGERMANNIACEÆ

1. Leaves undivided and with entire margins 2
   Leaves variously toothed, lobed, cleft, or divided 9
2. Archegonia borne on the stem or a leading branch 3
   Archegonia borne on a short branch, usually arising ventrally 7
3. Bracts undivided, similar to the leaves 4
   Bracts variously incised or cleft .... **Jamesoniella**, p. 52
4. Uppermost bracts apparently adnate with the base of the perianth .... **Nardia**, p. 50
   Uppermost bracts entirely free from the perianth 5
5. Perianth terete and more or less contracted at the mouth **Jungermannia**, p. 51
   Perianth laterally compressed and truncate at the mouth 6
6. Growing in damp or wet woods on various substrata; stems with few or no rhizoids; leaves never gemmiparous **Plagiochila**, p. 56
   Growing in open bogs; stems with numerous rhizoids; leaves often gemmiparous .... **Mylia**, p. 56
7. Leaves succubous; sporophyte enclosed within a perianth 8
   Leaves incubous; sporophyte developed within a pendent perigynium .... **Calypogeia**, p. 62
8. Leaf cells without trigones .... **Chiloscyphus**, p. 58
   Leaf cells with distinct trigones .... **Odontoschisma**, p. 62

9. Leaves not complicate, usually expanded in one plane.... 10
Leaves distinctly complicate, the two portions meeting at a more or less distinct keel........................... 22

10. Leaves succubous 11
Leaves incubous 19

11. Leaves bidentate or bilobed.............................. 12
Leaves with more than two teeth or lobes.............. 18

12. Underleaves distinct 13
Underleaves none or very minute........................ 16

13. Underleaves distinctly bifid............................. 14
Underleaves undivided or with a few marginal teeth or cilia 15

14. Sporophyte enclosed within a perianth....**Lophocolea,** p. 57
Sporophyte developed within a pendent perigynium **Geocalyx,** p. 59

15. Growing on rotten logs, often gemmiparous.............. **Harpanthus,** p. 59
Growing on calcareous rocks, never gemmiparous........ **Lophozia Muelleri,** p. 53

16. Perianth terete, more or less plicate at the mouth........ **Lophozia,** p. 52
Perianth trigonous 17

17. Leaf cells 0.025-0.05 mm. in diameter.......**Cephalozia,** p. 59
Leaf cells 0.01-0.02 mm. in diameter.....**Cephaloziella,** p. 61

18. Leaves undivided, margin sharply toothed..**Plagiochila,** p. 56
Leaves with three or four broad teeth......**Lophozia,** p. 52

19. Leaves bidentate at the apex; ventral flagelliform branches none ....**Calypogeia,** p. 62
Leaves mostly with three or four teeth, lobes, or divisions 20

20. Stems apparently dichotomous; ventral flagelliform branches numerous ....**Bazzania,** p. 64
Stems pinnately branched; ventral flagelliform branches none 21

21. Divisions or lobes of leaves two or more cells wide, at least at the base; archegonia borne on short ventral branches ....**Lepidozia,** p. 65
Divisions of leaves only one cell wide throughout; archegonia borne on the main stem or on leading lateral branches ....**Blepharostoma,** p. 66

22. Ventral lobe of leaf equaling or surpassing the dorsal in size 23
Ventral lobe smaller than the dorsal.................... 26

23. Bracts apparently adnate to the base of the perianth.. **Marsupella,** p. 50
Bracts entirely free from the perianth.................. 24

24. Perianth strongly dorsi-ventrally compressed, not plicate in upper part..............................**Scapania,** p. 68
Perianth terete or slightly compressed, more or less plicate in upper part.. 25

25. Keels of leaves sharp....................**Diplophylleia,** p. 67
Keels of leaves blunt.....................**Sphenolobus,** p. 55

26. Leaves and underleaves with fringed margins............... 27
Leaves and underleaves (when present) with entire or denticulate margins 28

27. Plants green, often tinged with brown or red, growing in rather dry localities; leaf cells with trigones and a smooth cuticle ....**Ptilidium,** p. 66
Plants pale green or yellowish, growing on the ground in swamps; leaf cells thin-walled, with a minutely striolate cuticle ....**Trichocolea,** p. 67

28. Underleaves present 29
Underleaves none 33

29. Underleaves undivided 30
Underleaves bifid 31

30. Ventral lobe of leaf not inflated, attached to the stem by a narrow base..............................**Porella,** p. 70
Ventral lobe of leaf inflated and forming a small water-sac, attached to the stem by a broad base............ **Leucolejeunea,** p. 72

31. Ventral lobe of leaf attached to the stem by a broad base, forming an inflated water-sac..............**Lejeunea,** p. 72
Ventral lobe of leaf usually forming an inflated water-sac, entirely free from the stem.......................... 32

32. Archegonial branch with one or two subfloral innovations **Jubula,** p. 72
Archegonial branch without subfloral innovations........ **Frullania,** p. 73

33. Dorsal lobes of leaves smooth and entire; perianth dorsi-ventrally compressed, truncate at the mouth.......... **Radula,** p. 69
Dorsal lobes of leaves denticulate and minutely roughened on outer surface by projecting cells; perianth inflated, five-keeled, and contracted at the mouth into a tubular beak ....**Cololejeunea,** p.

Marsupella Dumort.

Plants varying from green to reddish; leaves with a broad sinus and bluntly pointed lobes..............**M. emarginata**
Plants varying from green to deep purplish black; leaves with a narrow sinus and rounded lobes.......**M. Sullivantii**

Marsupella emarginata (Ehrh.) Dumort.

On damp shaded rocks. May and June. LITCHFIELD: Salisbury, *Nichols.* NEW HAVEN: Branford, *Evans;* Middlebury, *Harger;* Naugatuck, *Evans;* Oxford, *Harger;* Woodbridge (1879), *J. A. Allen.*

Labrador west to Alaska and south to Virginia, Minnesota, and California; Europe; Asia.

REF. Evans, **28,** 172.

Marsupella Sullivantii (DeNot.) Evans. *Marsupella sphacelata* of some authors, not (Gieseke) Dumort. *M. media* (Gottsche) Schiffn.

On shaded rocks. May and June. HARTFORD: Southington, *Miss Lorenz.* NEW HAVEN: Hamden and Naugatuck (1890), *Evans.*

Nova Scotia south to Georgia; Washington; Europe.

REF. Evans, **28,** 172; **30,** 167; **33,** 57.

Nardia S. F. Gray

1. Growing on sandy soil; rhizoids colorless; leaves (or at least the bracts) bordered by a row of thick-walled cells; leaf cells otherwise thin-walled throughout or with minute trigones ....**N. crenulata**
   Growing on damp rocks or banks; rhizoids more or less tinged with purple; leaf cells with distinct trigones.... 2
2. Leaves bordered by a row of thick-walled cells.......... **N. crenuliformis**
   Leaves not bordered, their cell structure uniform throughout ....**N. hyalina**

Nardia crenulata (Sm.) Lindb. *Jungermannia crenulata* Sm.

On sandy soil, especially along roadsides and shaded paths. April-June. LITCHFIELD: Cornwall and Litchfield, *Underwood.* TOLLAND: Bolton, *Nichols.* FAIRFIELD: Huntington

and Redding, *Evans*. New Haven: Hamden, *Eaton;* Meriden, *Evans;* New Haven (1866), *Eaton;* Orange, *Evans;* Oxford, *Harger;* Woodbridge, *J. A. Allen.* Middlesex: Middlefield, *Evans*.

Greenland west to British Columbia and south to Alabama and California; Europe; Asia.

Exsic. Underwood & Cook, Hep. Amer. No. 57.

Ref. Eaton, **15**, 71. Evans, **28**, 172.

Nardia crenuliformis (Aust.) Lindb.

On rocks along streams. May and June. New Haven: Beacon Falls (1907), *Evans*.

Connecticut to Ohio and south to New Jersey and West Virginia.

Nardia hyalina (Lyell) Carr.

On damp shaded rocks and banks. May and June. Windham: Canterbury, *Mrs. Hadley*. New Haven: Ansonia (1880), *J. A. Allen;* Beacon Falls, *Evans;* Hamden, *J. A. Allen;* Naugatuck, *Evans*. Middlesex: Middletown, *Evans*.

New England to Minnesota and south to Maryland; Europe; Peru.

Ref. Evans, **26**, 209; **28**, 172.

Jungermannia (Rupp.) L.

1. Leaf cells with trigones; monoicous: perianth abruptly contracted at the apex into a short depressed beak.... **J. lanceolata**
   Leaf cells without trigones; perianth gradually contracted at the apex 2
2. Small species, stems 5-10 mm. long; monoicous......**J. pumila**
   Large species, stems mostly 2-8 cm. long; dioicous...... **J. cordifolia**

Jungermannia lanceolata L. *Liochlæna lanceolata* Nees.

On shaded banks. May and June. New Haven: Hamden (1877) and New Haven, *J. A. Allen;* Oxford, *Harger*.

Labrador west to British Columbia and south to New Jersey, Indiana, and Washington; Europe; Asia; Madeira Islands.

Ref. Eaton, **15**, 71. Evans, **28**, 171.

Jungermannia pumila With.

On wet rocks, often in brooks. May and June. New Haven: Hamden (1877), *J. A. Allen;* North Branford, *Evans.*

Greenland south to Maryland; Europe.

Ref. Evans, **28,** 171.

Jungermannia cordifolia Hook.

On wet rocks along streams. Hartford: Windsor (1903), *Miss Lorenz.*

Greenland west to Alaska and south to New England and Colorado; Europe; Asia; South America.

Ref. Evans, **30,** 170.

Jamesoniella (Spruce) Steph.

Jamesoniella autumnalis (DC.) Steph. *Jungermannia Schraderi* Mart.

On banks, rocks, and rotten logs. Sept.-Nov. Litchfield: New Milford, *Evans;* Salisbury, *Adams.* Hartford: Simsbury, *Miss Lorenz.* Tolland: Vernon, *Nichols.* New Haven: Bethany, *Evans;* Hamden (1878), *Eaton;* Naugatuck, *Evans;* New Haven, *O. D. Allen;* Orange, *Evans;* Oxford, *Harger;* Woodbridge, *Nichols.* Middlesex: Cromwell, *Evans.*

Greenland to British Columbia and south to Virginia and Missouri; Europe; Asia.

Ref. Eaton, **15,** 71. Evans, **28,** 171.

Lophozia Dumort.

1. Leaves bidentate or bilobed throughout 2
   Leaves tri- or quadridentate, at least on fertile stems, sometimes bidentate on poorly developed stems 7
2. Teeth or lobes acute 3
   Teeth or lobes rounded .... **L. inflata**
3. Underleaves none; perianth plicate in upper part, and not strongly contracted at the mouth 4
   Underleaves present; perianth scarcely plicate in upper part, and contracted at the mouth into a short beak. . **L. Muelleri**
4. Dioicous 5
   Monoicous (paroicous) 6

5. Growing on rocks; leaf cells with small trigones..**L. ventricosa**
Growing on rotten logs; leaf cells with large trigones.. **L. porphyroleuca**

6. Plants with a distinct aromatic odor; leaf cells with strongly thickened walls ....**L. bicrenata**
Plants odorless; leaf cells thin-walled, but with small trigones ....**L. excisa**

7. Plants firm, dark green; leaves but little altered when dry 8
Plants delicate, pale or bright green; leaves strongly crispate when dry 10

8. Teeth of leaves subequal, the lateral margins nearly straight and of about the same length.................. 9
Apical (or ventral) tooth larger than the others, the corresponding lateral margin long and strongly curved.. **L. Lyoni**

9. Gemmæ usually abundant, borne on upright flagelliform shoots with closely appressed leaves..........**L. attenuata**
Gemmæ rare, not borne on flagelliform shoots......**L. barbata**

10. Lobes of leaves more or less toothed ....**L. incisa**
Lobes of leaves entire...........................**L. marchica**

Lophozia inflata (Huds.) M. A. Howe.

On damp shaded rocks. TOLLAND: Bolton, *Nichols*. NEW HAVEN: Branford (1892) and Naugatuck, *Evans*.

Greenland to Alaska and south to New Jersey and California; Europe; Asia.

REF. Evans, **28**, 172.

Lophozia Muelleri (Nees) Dumort.

In crevices of calcareous rocks. May and June. LITCHFIELD: Salisbury (1897), *Evans*.

Quebec to Connecticut; Europe; Asia.

REF. Evans, **32**, 35.

Lophozia bicrenata (Schmid.) Dumort. *Jungermannia excisa* of some authors.

On rocks, shaded earth, and banks. May and June. LITCHFIELD: Goshen, *Underwood*. TOLLAND: Bolton and Vernon, *Nichols*. FAIRFIELD: Huntington, *Evans*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1878), *J. A. Allen;* Meriden, *Evans;* Orange, *J. A. Allen;* Seymour, *Harger*.

Quebec and Ontario south to Pennsylvania and New Jersey; Europe; Asia.

REF. Eaton, **15**, 71. Evans, **26**, 209; **28**, 172.

Lophozia excisa (Dicks.) Dumort.

On rocks. NEW HAVEN: North Haven (1906), *Evans*.

Labrador to New England and west to British Columbia; Europe; Asia. The species has been confused in North America with *L. bicrenata*, and its range is therefore not very definitely known.

REF. Evans, **33**, 73. Miss Haynes, **44**, 99, *pl. 9, f. 10-13*.

Lophozia ventricosa (Dicks.) Dumort.

On rocks. LITCHFIELD: Salisbury (1908), *Miss Lorenz*.

Greenland to Alaska, south to New England, Minnesota, and California; Europe; Asia.

Lophozia porphyroleuca (Nees) Schiffn.

On rotten logs. TOLLAND: Stafford (1906), *Nichols*.

Greenland to British Columbia, south to New England and Washington; Europe; Asia.

REF. Evans, **33**, 73.

Lophozia marchica (Nees) Steph. *Jungermannia Novæ-Cæsareæ* Evans. *L. Novæ-Cæsareæ* Steph.

In bogs and on wet sandy soil. May and June. FAIRFIELD: Huntington, *Evans*. NEW HAVEN: East Haven (1892) and Orange, *Evans*.

New England south to Delaware and West Virginia; Europe.

REF. Evans, **20**, 309; **26**, 212; **28**, 172. Stephani, **67**², 153.

Lophozia incisa (Schrad.) Dumort.

On shaded banks and rotten logs. May and June. LITCHFIELD: Winchester, *Miss Lorenz*. TOLLAND: Stafford, *Nichols*. NEW HAVEN: Hamden (1877), *O. D. Allen;* Woodbridge, *Evans*.

Greenland to Alaska, and south to New England, Minnesota, and California; Europe; Asia.

REF. Evans, **28**, 172.

Lophozia barbata (Schreb.) Dumort. *Jungermannia barbata* Schreb.

On rocks. May and June. LITCHFIELD: Goshen, *Underwood.* HARTFORD: Farmington, *Miss Lorenz.* NEW HAVEN: East Haven, *Evans;* Hamden, *J. A. Allen;* Meriden, *Evans;* New Haven (1877), *J. A. Allen;* Southbury, *Harger.* MIDDLESEX: Durham, *Evans.*

Greenland to Yukon, and south to New York and New Jersey; Europe; Asia.

REF. Eaton, **15,** 71. Evans, **28,** 172.

Lophozia attenuata (Mart.) Dumort. *L. gracilis* (Schleich.) Steph.

On shaded rocks and logs. LITCHFIELD: Salisbury (1892), *Evans.*

Greenland to Alaska, south to New England and New York; Europe; Asia.

REF. Evans, **31,** 58.

Lophozia Lyoni (Tayl.) Steph.

On shaded rocks. NEW HAVEN: Meriden (1890), *Evans.*

Greenland to Alaska, and south to New England and Minnesota; Europe; Asia.

REF. Evans, **26,** 210; **28,** 172.

Sphenolobus (Lindb.) Steph.

Dorsal lobe much smaller than the ventral, often tooth-like **S. exsectus**

Lobes subequal .... **S. Michauxii**

Sphenolobus exsectus (Schmid.) Steph.

On shaded rocks. LITCHFIELD: New Milford, *Evans.* NEW HAVEN: Branford (1903) and Naugatuck, *Evans.*

Quebec to British Columbia, south to West Virginia and Colorado; Europe; Asia.

REF. Evans, **28,** 173; **30,** 171.

Sphenolobus Michauxii (Web. f.) Steph.

On shaded rocks. LITCHFIELD: Salisbury (1892), *Evans.*

Labrador to British Columbia, south to Virginia and Minnesota; Europe; Asia.

REF. Evans, **31**, 58.

Plagiochila Dumort.

Leaves broadly ovate, entire or denticulate, the teeth more than ten .... **P. asplenioides**

Leaves narrowly ovate, sharply dentate, the teeth less than ten .... **P. Sullivantii**

Plagiochila asplenioides (L.) Dumort. Including *P. porelloides* Nees.

On rocks and banks, often in wet localities. May and June. LITCHFIELD: New Milford and Salisbury, *Evans*. HARTFORD: Burlington, *Nichols*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Huntington, *Evans;* Redding, *Miss Haynes;* Sherman, *Evans*. NEW HAVEN: Beacon Falls, *Evans;* Bethany, *Hall;* Hamden (1855), New Haven, and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Evans*. MIDDLESEX: Cromwell, *Evans;* Killingworth, *Hall;* Middlefield and Middletown, *Evans*. NEW LONDON: Ledyard, *Nichols*.

Newfoundland to Alaska, and south to Virginia, Minnesota, and California; Europe; Asia.

REF. Eaton, **15**, 71. Evans, **28**, 172.

Plagiochila Sullivantii Gottsche. *P. spinulosa* of some authors.

On shaded rocks. FAIRFIELD: Redding, *Evans*. NEW HAVEN: Branford and Naugatuck (1890), *Evans*.

New Hampshire to North Carolina.

EXSIC. Underwood & Cook, Hep. Amer. No. 111 (as *P. spinulosa*), collected at Naugatuck, *Evans*, but incorrectly labeled "Beacon Falls."

REF. Evans, **21**, 191, *pl. 15, f. 18, 21, pl. 16, f. 1-3;* **28**, **172**. Stephani, **67**[2], 319.

Mylia S. F. Gray

Mylia anomala (Hook.) S. F. Gray.

Among Sphagna in bogs. LITCHFIELD: Woodbury, *Evans*. NEW HAVEN: Bethany (1892) and New Haven, *Evans*.

New Brunswick to Yukon, and south to New Jersey and Washington; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 151.

REF. Evans, **28**, 172. Underwood, **73**, 300.

Lophocolea Dumort.

1. Plants growing on wet rocks; leaves gradually narrowed toward the apex and divided into two sharp teeth; dioicous .... **L. bidentata**
   Plants growing on banks, rotten logs, or damp rocks; leaves scarcely narrowed toward the apex 2
2. Leaves varying from bifid to truncate and undivided; monoicous (paroicous); gemmæ none .... **L. heterophylla**
   Leaves bidentate; dioicous; gemmæ abundant, borne on rudimentary leaves .... **L. minor**

Lophocolea bidentata (L.) Dumort.

On rocks near or in streams. May and June. HARTFORD: Windsor, *Evans.* NEW HAVEN: Hamden (1877), *J. A. Allen;* Orange, *Evans.* MIDDLESEX: Cromwell, *Evans.*

Ontario south to Connecticut and Virginia; Europe; tropical and antarctic America.

EXSIC. Underwood & Cook, Hep. Amer. No. 95.

REF. Eaton, **15**, 71; Evans, **28**, 172.

Lophocolea heterophylla (Schrad.) Dumort. Including *L. Austini* Lindb.

On rotten logs, shaded banks, and earth in woods. May-July. LITCHFIELD: Goshen, *Underwood;* New Milford, *Evans;* Salisbury, *Nichols.* TOLLAND: Bolton and Stafford, *Nichols.* FAIRFIELD: Huntington and Sherman, *Evans.* NEW HAVEN: Beacon Falls and Derby, *Evans;* East Haven and Hamden, *O. D. Allen;* Meriden and Middlebury, *Evans;* New Haven (1866), *Eaton;* North Branford, North Haven, and Orange, *Evans;* Oxford, *Harger;* Seymour, *Evans.* MIDDLESEX: Durham, *Evans;* Killingworth, *Nichols;* Middlefield, *Evans.* NEW LONDON: Ledyard, *Nichols.*

Nova Scotia to British Columbia, and south to North Carolina, Minnesota, and California; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 186, in part (as *L. Austini*).

REF. Eaton, **15**, 71. Evans, **23**, *pl. 6;* **28**, 172.

Lophocolea minor Nees.

On shaded banks and rocks, especially in limestone regions. HARTFORD: Farmington and Hartford, *Miss Lorenz*. TOLLAND: Stafford, *Nichols*. FAIRFIELD: Sherman, *Evans*. NEW HAVEN: East Haven, *Evans;* New Haven (1877), *J. A. Allen*.

New Brunswick to British Columbia, south to New York and Minnesota; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 129.

REF. Evans, **28**, 172.

Chiloscyphus Corda

Leaf cells usually less than 0.03 mm. in diameter; lobes of perianth entire or nearly so .... **C. polyanthus**

Leaf cells mostly 0.035-0.04 mm. in diameter; lobes of perianth dentate or lacerate .... **C. pallescens**

Chiloscyphus polyanthus (L.) Corda.

In swamps and streams, often submerged. LITCHFIELD: Winchester, *Evans*. HARTFORD: Windsor, *Evans*. TOLLAND: Bolton and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Bethany (1878), *Eaton;* Hamden, *Harger;* New Haven, *Evans;* Oxford, *Harger;* Woodbridge, *J. A. Allen*. MIDDLESEX: Killingworth, *Nichols;* Middletown, *Evans*.

Labrador to Alaska, and south to New Jersey, Missouri, and California; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **28**, 171.

Chiloscyphus pallescens (Ehrh.) Dumort. *C. ascendens* Sulliv.

On rotten logs and shaded banks. May and June. LITCHFIELD: Salisbury, *Evans*. NEW HAVEN: Bethany (1875), *Eaton;* Hamden, *J. A. Allen;* Middlebury, *Evans;* New Haven, *Harger;* Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Evans*.

Ontario to British Columbia, south to New England, New York, and Indiana; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **28**, 171; **31**, 54.

Harpanthus Nees

Harpanthus scutatus (Web. f. & Mohr) Spruce.

On rotten logs. LITCHFIELD: Salisbury, *Evans*. TOLLAND: Stafford, *Nichols*. NEW HAVEN: Branford and Cheshire, *Evans;* Oxford (1890), *Harger*.

Labrador west to British Columbia and south to Virginia; Europe; Asia.

REF. Evans, **28**, 171.

Geocalyx Nees

Geocalyx graveolens (Schrad.) Nees.

On rotten logs, banks, and shaded rocks. May and June. LITCHFIELD: New Milford and Salisbury, *Evans*. HARTFORD: Windsor, *Evans*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Redding, *Miss Haynes*. NEW HAVEN: Beacon Falls, *Evans;* Hamden, *J. A. Allen;* New Haven (1867), *Veitch;* North Branford and North Haven, *Evans;* Oxford, *Harger;* Woodbridge, *Eaton*.

Nova Scotia to British Columbia, south to Virginia and Washington; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **28**, 171.

Cephalozia Dumort.

1. Stems bounded by a layer of enlarged cortical cells...... 2
   Stems uniform in cell structure; lobes of leaves obtuse or obtusely pointed .... **C. fluitans**
2. Leaves inflated at the base, the segments ending in long slender points .... **C. curvifolia**
   Leaves not inflated at the base, the segments acute or acuminate 3
3. Leaves not decurrent, symmetrical, the segments straight or scarcely connivent .... **C. bicuspidata**
   Leaves more or less decurrent, unsymmetrical, the segments connivent 4
4. Leaf cells 0.04-0.045 mm. in diameter............ **C. connivens**
   Leaf cells 0.02-0.03 mm. in diameter.................... 5

5. Leaf cells thin-walled; segments of bracts entire or sparingly laciniate .... **C. lunulæfolia**
Leaf cells with uniformly thickened walls; segments of bracts dentate or denticulate .... **C. serriflora**

Cephalozia curvifolia (Dicks.) Dumort.

On rotten logs. May and June. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Evans*. HARTFORD: Windsor, *W. E. Britton*. FAIRFIELD: Monroe and Newtown, *Harger*. NEW HAVEN: Beacon Falls, *Nichols;* Branford, *Evans;* Cheshire, *Harger;* Hamden (1877) and New Haven, *J. A. Allen;* North Haven and Woodbridge, *Evans*.

Newfoundland to Ontario, south to North Carolina and Minnesota; Europe; Asia.

REF. Eaton, **15**, 71. Evans, **28**, 171.

Cephalozia bicuspidata (L.) Dumort.

On shaded banks and rocks. May and June. LITCHFIELD: Salisbury, *Nichols*. TOLLAND: Stafford, *Nichols*. FAIRFIELD: Trumbull (1891), *Evans*. NEW HAVEN: Beacon Falls, Hamden, Naugatuck, and Orange, *Evans*.

Greenland to Alaska, and south to New England, Minnesota, and California; Asia; northern Africa.

REF. Eaton, **15**, 71 (quoted from East Haven). Evans, **28**, 171.

Cephalozia connivens (Dicks.) Lindb.

In swamps and wet pastures. May and June. LITCHFIELD: Salisbury, *Evans*. FAIRFIELD: Sherman, *Evans*. NEW HAVEN: East Haven and Hamden, *Evans*. New Haven (1867), *Eaton;* North Branford, *Evans*.

Prince Edward Island to Ontario, and south to Florida; Europe; Asia.

REF. Eaton, **15**, 71. Evans, **28**, 171. Howe, **49**, 282.

Cephalozia lunulæfolia Dumort.

On shaded banks and rotten logs. May and June. LITCHFIELD: Salisbury and Woodbury, *Evans*. HARTFORD: Windsor, *Evans*. TOLLAND: Bolton and Stafford, *Nichols*. FAIRFIELD: Huntington and Redding, *Evans*. NEW HAVEN: Beacon Falls and Hamden, *Evans;* New Haven (1866), *Eaton;*

North Branford, *Evans;* North Haven, *Nichols.* MIDDLESEX: Durham, *Evans.*

Greenland to Alaska, and south to Florida, Minnesota, and California; Europe; Asia.

REF. Evans, **28,** 171.

Cephalozia serriflora Lindb. *C. catenulata* of some authors.

On rotten logs. NEW HAVEN: New Haven (1892), *Evans.*

Nova Scotia to British Columbia, south to Florida and Louisiana; Europe; Asia.

REF. Evans, **28,** 171; **30,** 173.

Cephalozia fluitans (Nees) Spruce.

In wet bogs. LITCHFIELD: Salisbury and Woodbury, *Evans.* NEW HAVEN: Bethany (1888), *Harger.*

Labrador to British Columbia, south to New Jersey, Minnesota, and Washington; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 154.

REF. Evans, **28,** 171.

Cephaloziella (Spruce) Schiffn.

Dioicous .... **C. divaricata**
Monoicous (paroicous) .... **C. myriantha**

Cephaloziella divaricata (Sm.) Schiffn. *Cephalozia divaricata* Dumort.

On damp banks, sandy soil, and rocks. May and June. LITCHFIELD: Goshen, *Underwood.* HARTFORD: Hartford and West Hartford, *Miss Lorenz.* TOLLAND: Vernon, *Nichols.* FAIRFIELD: Huntington and Redding, *Evans.* NEW HAVEN: East Haven, *Evans;* Hamden (1877) and New Haven, *J. A. Allen;* North Haven, *Evans;* Orange, *J. A. Allen;* Oxford, *Harger;* Seymour, *Evans.* MIDDLESEX: Middlefield, *Evans.*

Greenland to Alaska, south to Maryland, Minnesota, and California; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 155.

REF. Eaton, **15,** 71. Evans, **28,** 171.

Cephaloziella myriantha (Lindb.) Schiffn.

On sandy soil and rocks. HARTFORD: East Granby and West Hartford (1907), *Miss Lorenz.*

New England and New York; range in North America not definitely known; Europe.

Odontoschisma Dumort.

Leaves bordered by one to three rows of rectangular cells; gemmæ none .... **O. prostratum**

Leaves uniform in cell structure; gemmæ usually abundant, borne at the tips of erect shoots with rudimentary leaves **O. denudatum**

Odontoschisma prostratum (Sw.) Trevis. *O. Sphagni* of some authors.

In swamps and bogs. HARTFORD: West Hartford, *Miss Lorenz.* TOLLAND: Columbia, *Weatherby.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Hamden (1866) and New Haven, *Eaton;* North Branford, *Evans;* Oxford, *Harger.* NEW LONDON: Waterford, *Miss Lorenz.*

Southern New England, south into tropical America.

REF. Eaton, **15,** 71. Evans, **28,** 172; **29,** 344, *pl. 19, f. 42-54, pl. 20, f. 55, 57, 59, 60, 63, 64.*

Odontoschisma denudatum (Mart.) Dumort.

On rotten logs, more rarely on shaded banks. LITCHFIELD: Salisbury, *Evans.* HARTFORD: Windsor, *Evans.* TOLLAND: Bolton and Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Hamden, *O. D. Allen;* North Branford (1881), *J. A. Allen.*

Greenland to Nova Scotia and Ontario, south into tropical America; Europe; Asia.

REF. Evans, **28,** 172; **29,** 342, *pl. 19, f. 35-38.*

Calypogeia Raddi

1. Leaves rounded to obtuse at the apex, rarely bifid or bidentate; leaf cells with a smooth cuticle.............. 2
   Leaves sharply bidentate; leaf cells with a minutely striate-verruculose cuticle ....**C. Sullivantii**
2. Leaf cells without trigones 3
   Leaf cells with small but distinct trigones................ 4

3. Plants robust, growing on banks, earth in woods, or shaded rocks; underleaves bifid about one-third.....**C. Trichomanis**
Plants delicate, growing in bogs, underleaves bifid to the middle or beyond ....**C. tenuis**

4. Growing in bogs; leaves spreading at an angle of about 30° **C. sphagnicola**
Growing on rotten logs; leaves spreading at an angle of about 45° ....**C. suecica**

Calypogeia Trichomanis (L.) Corda. *Kantia Trichomanis* S. F. Gray.

On shaded banks and earth in woods. May and June. LITCHFIELD: Salisbury and Woodbury, *Evans.* HARTFORD: Windsor, *Evans.* TOLLAND: Bolton, *Nichols;* Coventry, *Mrs. Phelps;* Stafford and Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Huntington, *Evans;* Redding, *Miss Haynes.* NEW HAVEN: Beacon Falls, *Evans;* Hamden (1877), *J. A. Allen;* Meriden, Naugatuck, New Haven, and Orange, *Evans.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Labrador to Alaska, and south to North Carolina and California; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **28**, 171; **33**, 70.

Calypogeia tenuis (Aust.) Evans.

In bogs. LITCHFIELD: Woodbury (1902), *Evans.*

New Hampshire to New Jersey.

REF. Evans, **33**, 69, *pl. 73, f. 9-14.*

Calypogeia sphagnicola (Arn. & Perss.) Warnst. & Loeske.

In bogs. LITCHFIELD: New Milford (1906), *Evans.*

The only known locality outside of Europe.

REF. Evans, **33**, 65.

Calypogeia suecica (Arn. & Perss.) C. Müll. Frib.

On rotten logs. TOLLAND: Stafford (1906), *Nichols.*

Maine to Connecticut; Europe; range not yet definitely known.

REF. Evans, **33**, 66.

Calypogeia Sullivantii Aust. *Kantia Sullivantii* Underw.

On sandy banks. NEW HAVEN: East Haven, *Evans;* Milford, *Weatherby;* Woodbridge (1890), *Evans.* NEW LONDON: Waterford, *Miss Lorenz.*

Southern New England to North Carolina and Arkansas.

REF. Evans, **26,** 212; **28,** 171; **33,** 67.

Bazzania S. F. Gray

Plants large, the leaves often 2.5 mm. long, broadly ovate, truncate and tridentate at the apex............**B. trilobata**

Plants smaller, the leaves mostly 0.7 to 1.2 mm. long, ovate, acute or irregularly bidentate or tridentate at the apex **B. tricrenata**

Bazzania trilobata (L.) S. F. Gray. *Mastigobryum trilobatum* Nees.

On earth in woods and swamps, on shaded banks, and on rotten logs. Autumn. LITCHFIELD: Goshen, *Underwood;* New Milford and Salisbury, *Evans.* HARTFORD: Canton, *Nichols;* Glastonbury, *Mrs. Lowe;* West Hartford, *Miss Lorenz.* TOLLAND: Ellington and Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Redding, *Miss Haynes.* NEW HAVEN: Beacon Falls and Branford, *Evans;* Hamden (1855), *Eaton;* Naugatuck, *Evans;* North Haven, *Nichols;* Orange, *Eaton;* Oxford, *Harger;* Seymour, *Evans;* Woodbridge, *Hall.* MIDDLESEX: Durham and Killingworth, *Evans.* NEW LONDON: Groton and North Stonington, *C. B. Graves.*

Newfoundland to Ontario, and south to Alabama; Europe; Asia.

REF. Eaton, **15,** 70. Evans, **28,** 171.

Bazzania tricrenata (Wahl.) Trevis. *B. triangularis* (Schleich.) Lindb.

On shaded rocks. LITCHFIELD: Salisbury (1892), *Evans.* FAIRFIELD: Redding, *Evans.* NEW HAVEN: Beacon Falls and Naugatuck, *Evans.*

Nova Scotia to Alaska, and south to North Carolina and Washington; Europe; Asia.

REF. Evans, **28,** 171.

Lepidozia Dumort.

1. Leaves divided to the middle or a little beyond into three or four triangular lobes .... **L. reptans**
   Leaves divided almost to the base into three or four setaceous divisions 2
2. Underleaves of stem mostly quadrifid with subequal divisions; bracts mostly trifid or quadrifid........ **L. setacea**
   Underleaves of stem mostly trifid, one or two of the divisions regularly aborted; bracts mostly bifid.... **L. sylvatica**

Lepidozia reptans (L.) Dumort.

On shaded banks and rotten logs. May and June. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Evans.* HARTFORD: Canton, *Nichols.* WINDHAM: Windham, *Nichols.* NEW HAVEN: Beacon Falls, *Evans;* Hamden, *Eaton;* Naugatuck, *Evans;* New Haven, *J. A. Allen;* North Haven, *Evans;* Orange (1877), *J. A. Allen;* Oxford, *Harger;* Woodbridge, *J. A. Allen.*

Newfoundland to Alaska, and south to Virginia, Minnesota, and California; Europe; Asia.

REF. Eaton, **15,** 70. Evans, **28,** 172.

Lepidozia setacea (Web.) Mitt. *L. sphagnicola* Evans.

In bogs. May and June. NEW HAVEN: Bethany (1892), *Evans.*

Range in North America not definitely known; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 168 (as *L. sphagnicola*).

REF. Evans, **20,** 308, *pl. 162;* **28,** 172; **30,** 186.

Lepidozia sylvatica Evans. *L. setacea* of some authors.

On shaded banks and rotten logs. May and June. HARTFORD: Manchester, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven, *Evans;* Hamden (1866) *Eaton;* Naugatuck, *Evans;* New Haven, *Veitch;* Orange, *Eaton;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Hall.*

New England to Florida.

EXSIC. Underwood & Cook, Hep. Amer. No. 85 (as *L. setacea*).

REF. Eaton, **15,** 70. Evans, **28,** 172; **30,** 187, *pl.* 57.

Blepharostoma Dumort.

Blepharostoma trichophyllum (L.) Dumort.

On shaded banks and rocks, also on rotten logs. May and June. TOLLAND: Stafford, *Nichols*. FAIRFIELD: Sherman, *Evans*. NEW HAVEN: Beacon Falls, *Evans;* New Haven, *J. A. Allen;* Orange, *Evans*. MIDDLESEX: Killingworth (1875), *Hall*.

Greenland to Alaska, and south to New Jersey, Colorado, and California; Europe; Asia.

REF. Eaton, **15,** 70. Evans, **28,** 171.

Ptilidium Nees

Stems erect or ascending; stem leaves distant or loosely imbricated .... **P. ciliare**

Stems prostrate; stem leaves densely imbricated........ **P. pulcherrimum**

Ptilidium ciliare (L.) Nees. *Blepharozia ciliaris* Dumort.

On earth among rocks. May and June. LITCHFIELD: Cornwall and Goshen, *Underwood*. NEW HAVEN: East Haven, *Evans;* Hamden (1877), *J. A. Allen;* Meriden, *Miss Lorenz*. MIDDLESEX: Durham, *Evans*. NEW LONDON: Norwich, *C. B. Graves*.

Greenland to Alaska, and south to New England and Minnesota; Europe; Asia.

REF. Eaton, **15,** 70. Evans, **28,** 172; **32,** 44.

Ptilidium pulcherrimum (Web.) Hampe. Included under *P. ciliare* by many writers.

On shaded rocks, trunks of trees, and rotten logs; rarely on banks rich in humus. May and June. LITCHFIELD: Cornwall and Goshen, *Underwood;* New Milford and Salisbury, *Evans*. HARTFORD: Burlington and Canton, *Nichols;* TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Redding and Sherman, *Evans*. NEW HAVEN: Beacon Falls, *Evans;* Bethany, Ham-

den, and Meriden (1856), *Eaton;* New Haven, North Haven, and Seymour, *Evans;* Woodbridge, *J. A. Allen.* MIDDLESEX: Durham, *Evans.*

Nova Scotia to Alaska, and south to Virginia, Minnesota, and Montana; Europe; Asia.

REF. Evans, **32**, 43.

Trichocolea Dumort.

Trichocolea tomentella (Ehrh.) Dumort.

On earth and banks in wooded swamps. LITCHFIELD: Norfolk, *Miss Lorenz;* Salisbury, *Evans.* HARTFORD: Windsor, *Evans.* FAIRFIELD: Danbury, *Eaton.* NEW HAVEN: Beacon Falls and Branford, *Evans;* East Haven, Hamden, and New Haven (1865), *Eaton;* Orange and Woodbridge, *Evans.* MIDDLESEX: East Haddam, *C. B. Graves;* Killingworth, *Hall.*

Newfoundland to Ontario, and south to North Carolina; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **28**, 173.

Diplophylleia Trevis.

Ventral lobe apiculate; monoicous (autoicous)....**D. apiculata**
Ventral lobe rounded; dioicous....................**D. taxifolia**

Diplophylleia apiculata Evans. *Scapania albicans* var. *taxifolia* (Wahl.) Aust. *Scapania albicans* var. *taxifolia minor* Aust.

On shaded banks, more rarely on rocks. May and June. LITCHFIELD: New Milford and Salisbury, *Evans.* HARTFORD: Burlington and Canton, *Nichols;* Hartford, *Miss Lorenz.* TOLLAND: Bolton and Vernon, *Nichols.* FAIRFIELD: Huntington, *Evans;* Redding, *Howe.* NEW HAVEN: Beacon Falls, *Evans;* Hamden, *O. D. Allen;* Madison, Meriden, Naugatuck, North Haven, Orange, and Seymour, *Evans;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Hall* (1876).

Southern New England to Georgia.

EXSIC. Miss Haynes, Amer. Hep. No. 33.

REF. Eaton, **15**, 71. Evans, **27**, 373, *pl. 12.* **28**, 171.

Diplophylleia taxifolia (Wahl.) Trevis.

On shaded rocks. LITCHFIELD: Salisbury (1890), *Evans*. NEW HAVEN: Branford, *Evans*.

Newfoundland to Alaska, south to New England, Idaho, and Washington; Europe; Asia.

REF. Evans, **28**, 171.

Scapania Dumort.

1. Ventral lobe obtuse, acute, or apiculate, mostly entire.... 2
   Ventral lobe rounded 3
2. Growing on earth or rocks; stems usually less than 2 cm. long ....**S. curta**
   Growing in bogs; stems mostly 2-10 cm. long......**S. irrigua**
3. Growing on rocks or banks; leaves mostly toothed or ciliate 4
   Growing on wet rocks, usually in streams; leaves mostly entire, the dorsal lobe arching beyond stem; leaf cells thin-walled ....**S. undulata**
4. Bright green, varying to yellowish or brownish; dorsal lobe arching beyond stem; leaf cells with uniformly thickened walls except near base; leaf margins mostly ciliate ....**S. nemorosa**
   More or less tinged with red; dorsal lobe scarcely arching across stem; leaf cells with thin walls but with more or less evident trigones; leaf margins mostly dentate **S. dentata**

Scapania curta (Mart.) Dumort.

On rocks. NEW HAVEN: Meriden (1907), *Miss Lorenz*.

Greenland to Alaska, south to Maryland and California; Europe; Asia.

Scapania irrigua (Nees) Dumort.

In bogs. LITCHFIELD: Winchester, *Evans*. NEW HAVEN: Bethany (1892), *Evans*.

Greenland to Alaska, south to New Jersey and British Columbia; Europe; Asia.

EXSIC. Underwood & Cook, Hep. Amer. No. 190 (Bethany, *F. Bement*, incorrectly labeled, "Lebanon, Ct.").

REF. Evans, **28**, 172. Müller, **60**, 80.

Scapania nemorosa (L.) Dumort.

On rocks and banks. May and June. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Evans.* HARTFORD: Hartford, *Miss Lorenz;* Southington, *Chamberlain.* TOLLAND: Bolton, Stafford, and Vernon, *Nichols.* WINDHAM: Plainfield, *Sheldon;* Windham, *Nichols.* FAIRFIELD: Bridgeport, *Miss Lorenz;* Huntington, *Evans;* Redding, *Miss Haynes.* NEW HAVEN: Beacon Falls, Bethany, and Branford, *Evans;* Hamden, *Eaton;* Meriden and Naugatuck, *Evans;* New Haven (1855), *Eaton;* Orange, *Evans;* Oxford, *Harger;* Seymour, *Evans;* Woodbridge, *Hall.* MIDDLESEX: Killingworth and Middletown, *Evans.* NEW LONDON: Norwich, *C. B. Graves.*

Nova Scotia to Alaska, south to Georgia, Louisiana, and California; Europe.

REF. Eaton, **15**, 71. Evans, **28**, 172. Müller, **60**, 173.

Scapania dentata Dumort.

On damp rocks. HARTFORD: Burlington (1908), *Nichols.*

New England, Minnesota, Montana, British Columbia, and California; Europe; Asia; range in North America not definitely known.

Scapania undulata (L.) Dumort.

On wet rocks, usually in streams. LITCHFIELD: Salisbury, *Miss Lorenz.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Redding, *Miss Haynes.* NEW HAVEN: Beacon Falls, *A. H. Graves;* Hamden, *Eaton;* North Branford, *Evans;* Woodbridge (1878), *J. A. Allen.* MIDDLESEX: Chester, *Nichols.* NEW LONDON: Montville, *C. B. Graves.*

Greenland to Alaska, south to Florida, Missouri, and California; Europe; Asia.

REF. Evans, **28**, 173. Müller, **60**, 133.

Radula Dumort.

1. Plants pale or bright green; ventral lobes of stem leaves not arching across axis, attached by a long and almost longitudinal line; leaf cells thin-walled throughout or with very indistinct trigones; monoicous (usually paroicous) 2

Plants often tinged with brown; ventral lobes of stem leaves arching partially or wholly across the axis, and attached by a short oblique line; leaf cells with distinct trigones; dioicous .... **R. tenax**

2. Subfloral innovations usually none.............. **R. complanata**
Subfloral innovations single or double............ **R. obconica**

Radula complanata (L.) Dumort.

On rocks and trunks of trees. May and June. LITCHFIELD: Goshen, *Underwood;* New Milford, *Evans.* HARTFORD: Windsor, *W. E. Britton.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Redding, *Miss Haynes;* Sherman, *Evans.* NEW HAVEN: Cheshire, *Harger;* Hamden and New Haven (1866), *Eaton;* North Haven, Orange, and Seymour, *Evans.* MIDDLESEX: Killingworth and Middlefield, *Evans.*

REF. Eaton, **15**, 70. Evans, **28**, 172.

Quebec to Alaska, south to Florida, Louisiana, and California; Europe; Asia; northern Africa.

Radula obconica Sull.

On shaded rocks in ravines. FAIRFIELD: Redding, *Evans.* NEW HAVEN: Hamden (1891), *Evans;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.*

Connecticut west to Ohio and south to Georgia.

REF. Evans, **26**, 213; **28**, 172.

Radula tenax Lindb.

On shaded rocks. LITCHFIELD: Salisbury, *Miss Lorenz;* FAIRFIELD: Redding, *Miss Haynes.* NEW HAVEN: Branford and Naugatuck (1890), *Evans.*

New England to North Carolina.

REF. Evans, **28**, 172.

Porella (Dill.) L.

1. Ventral lobes lingulate-oblong, closely appressed to the stem or to the dorsal lobes...................... **P. pinnata**
Ventral lobes broadly ovate to oblong.................... **2**

2. Ventral lobes slightly or not at all decurrent; underleaves contiguous or slightly imbricated............. **P. platyphylla**
Ventral lobes long-decurrent; underleaves distant.. **P. rivularis**

Porella pinnata L. *Madotheca Porella* Dumort.

On stones and trunks of trees, subject to inundation. LITCHFIELD: Goshen, *Underwood.* HARTFORD: Granby, *Nichols.* FAIRFIELD: Danbury, *Nichols;* Greenwich, *Miss Haynes;* Redding, *Evans.* NEW HAVEN: Cheshire, *Nichols;* East Haven (1859), *Eaton;* Hamden, *J. A. Allen;* New Haven, *Eaton;* North Branford and Orange, *Evans.* MIDDLESEX: Killingworth, *Hall;* Middlefield, *Evans.*

Nova Scotia to Ontario, south to Georgia and Louisiana; Europe.

EXSIC. Underwood & Cook, Hep. Amer. No. 9.

REF. Eaton, **15**, 70. Evans, **28**, 172.

Porella platyphylla (L.) Lindb. *Madotheca platyphylla* Dumort.

On shaded rocks and trunks of trees. May and June. LITCHFIELD: Goshen, *Underwood;* New Milford and Salisbury, *Evans.* HARTFORD: Southington, *Chamberlain;* Windsor, *W. E. Britton.* TOLLAND: Bolton, Stafford, and Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Killingly, *Rounds;* Plainfield, *Sheldon;* Windham, *Nichols.* FAIRFIELD: Danbury, *Eaton;* Redding, *Miss Haynes;* Sherman, *Evans.* NEW HAVEN: Bethany, East Haven, and Hamden (1858), *Eaton;* Meriden, *Evans;* New Haven, *Eaton;* Orange, *Evans;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Hall.* NEW LONDON: East Lyme, *C. B. Graves.*

Nova Scotia west to Alaska and south to Georgia and Missouri; Europe; Asia; northern Africa.

REF. Eaton, **15**, 70. Evans, **28**, 172. Howe, **47**, 522.

Porella rivularis (Nees) Trevis.

On shaded rocks. NEW HAVEN: Cheshire (1856), *Eaton.*

Connecticut and Ohio, south to Texas and New Mexico, west to California, British Columbia, and Alaska; Europe.

REF. Barbour, **6**, 35. Evans, **28**, 172. Howe, **47**, 520.

Cololejeunea (Spruce) Schiffn.

Cololejeunea Biddlecomiæ (Aust.) Evans. *Lejeunea echinata* and *L. calcarea* of some authors.

On rocks and trees. May and June. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Evans.* HARTFORD: Manchester and West Hartford, *Miss Lorenz.* FAIRFIELD: Sherman, *Nichols.* NEW HAVEN: Bethany, *Evans;* Hamden (1877) and New Haven, *J. A. Allen.*

New England to Ontario, south to Florida and Alabama.

REF. Eaton, **15**, 70. Evans, **25**, 169; **28**, 171.

Lejeunea Libert

Lejeunea cavifolia (Ehrh.) Lindb. *L. serpyllifolia* Libert.

On shaded rocks and trees. May and June. LITCHFIELD: Salisbury, *Nichols.* FAIRFIELD: Redding and Trumbull, *Evans.* NEW HAVEN: Branford, *Evans;* Hamden and New Haven, *J. A. Allen;* Orange, *Evans;* Oxford, *Harger;* Seymour, *Evans.* MIDDLESEX: Killingworth (1875), *Hall;* Middletown, *Evans.*

New England west to Ontario and Minnesota and south to Pennsylvania; Europe; Asia.

REF. Eaton, **15**, 70. Evans, **25**, 152; **28**, 171.

Leucolejeunea Evans

Leucolejeunea clypeata (Schwein.) Evans. *Phragmicoma clypeata* Nees. *Archilejeunea clypeata* Schiffn.

On rocks and trees. May and June. LITCHFIELD: New Milford and Salisbury, *Evans.* FAIRFIELD: Redding, *Evans.* NEW HAVEN: Cheshire, *Harger;* Hamden, *J. A. Allen;* Meriden, *Miss Lorenz;* New Haven and North Haven, *Evans;* Oxford, *Harger;* Seymour and Woodbridge, *Evans.* MIDDLESEX: Killingworth (1875), *Hall.*

Southern New England and New York, south to Georgia and Louisiana.

REF. Barbour, 7, 29. Eaton, **15**, 70. Evans, **25**, 124, *pl. 16, f. 1-11;* **28**, 171.

Jubula Dumort.

Jubula pennsylvanica (Steph.) Evans. *Frullania* and *Jubula Hutchinsiæ* of some authors.

On damp, often dripping, rocks. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Evans.* HARTFORD: Windsor, *Evans.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Redding, *Miss Haynes.* NEW HAVEN: Beacon Falls and Cheshire, *Evans;* Derby, *J. A. Allen;* Hamden (1866), *Eaton;* Naugatuck, *Evans;* Woodbridge, *Hall.* MIDDLESEX: Middletown, *Evans.*

Nova Scotia to Georgia and Tennessee.

EXSIC. Underwood & Cook, Hep. Amer. No. 100 (as *J. Hutchinsiæ* var. *Sullivantii*). Miss Haynes, Amer. Hep. No. 34.

REF. Eaton, **15**, 69. Evans, **28**, 171; **31**, 56.

Frullania Raddi

1. Ventral lobes about as broad as long; leaves without ocelli ... 2
   Ventral lobes distinctly longer than broad; leaves with ocelli ... 6
2. Underleaves cordate at base ... **F. plana**
   Underleaves not cordate at base ... 3
3. Leaves strongly squarrose when moist ... **F. squarrosa**
   Leaves scarcely or not at all squarrose ... 4
4. Ventral lobes usually explanate ... **F. riparia**
   Ventral lobes usually inflated ... 5
5. Underleaves dentate or crenate above the middle .. **F. Brittoniæ**
   Underleaves entire or unidentate on the sides .. **F. eboracensis**
6. Dorsal lobes rounded or very obtuse ... **F. Asagrayana**
   Dorsal lobes more or less sharp-pointed ... **F. Tamarisci**

Frullania riparia Hampe.

On shaded rocks, especially limestone. LITCHFIELD: New Milford, *Evans;* Salisbury, *Nichols.* FAIRFIELD: Sherman and Trumbull (1891), *Evans.* NEW HAVEN: Orange, *Evans.*

New England to Minnesota, south to Tennessee; Europe; Asia.

REF. Evans, **22**, *pl. 5, f. 1, 4, 5;* **28**, 171.

Frullania squarrosa (R. Bl. & N.) Dumort.

On rocks and trees. NEW HAVEN: East Haven (1890), *Evans.*

Connecticut to Ohio, and south into the tropics of South America; Asia; Africa; Australia.

REF. Barbour, **5**, 4. Evans, **22**, 15; **28**, 171.

Frullania Brittoniæ Evans.

On rocks and trees. May and June. LITCHFIELD: New Milford, *Evans*. NEW HAVEN: Hamden, *J. A. Allen;* Meriden, *Evans;* New Haven (1866), *Eaton*.

New England west to Illinois, south to Virginia.

REF. Barbour, **5**, 5. Evans, **22**, 16, *pl. 7, f. 1-12;* **28**, 171.

Frullania eboracensis Gottsche. Including *F. virginica* Gottsche.

On trees and rocks. May and June. LITCHFIELD: Cornwall, *Green;* Goshen, *Underwood;* New Milford and Salisbury, *Evans*. TOLLAND: Stafford and Vernon, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley;* Plainfield, *Sheldon*. FAIRFIELD: Greenwich, *Miss Haynes;* Huntington, *Nichols;* Sherman, *Evans*. NEW HAVEN: Bethany, *Evans;* East Haven, *Eaton;* Hamden, *Hall;* Milford, *Harger;* New Haven (1866), *Eaton;* North Haven, *J. A. Allen;* Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Eaton*. MIDDLESEX: Chester and Killingworth, *Nichols*. NEW LONDON: Groton, *C. B. Graves;* Ledyard, *Nichols*.

Nova Scotia to Manitoba, south to Florida.

REF. Eaton, **15**, 69. Evans, **28**, 171; **32**, 44.

Frullania plana Sull.

On shaded rocks. NEW HAVEN: Woodbridge (1890), *Evans*.

Connecticut and New York, south to New Jersey and Tennessee.

REF. Barbour, **4**, 5. Evans, **22**, 20; **28**, 171.

Frullania Asagrayana Mont. Sometimes called *F. Grayana*.

On rocks and trees. LITCHFIELD: New Milford and Salisbury, *Evans*. TOLLAND: Stafford, *Nichols*. WINDHAM: Can-

terbury, *Mrs. Hadley*. FAIRFIELD: Redding and Sherman, *Evans*. NEW HAVEN: East Haven, Madison, and Meriden, *Evans;* New Haven (1855), *Eaton;* Orange and Woodbridge, *Harger*. MIDDLESEX: Killingworth, *Hall*.

Newfoundland to Ontario, south to Georgia.

REF. Eaton, **15**, 69. Evans, **28**, 171.

Frullania Tamarisci (L.) Dumort.

On rocks and trees. NEW HAVEN: Seymour (1904), *Evans*.

Newfoundland to Connecticut; Europe; Asia. Range not definitely known in North America.

REF. EVANS, **33**, 72.

ORDER ANTHOCEROTALES

FAMILY ANTHOCEROTACEÆ

Capsule scarcely projecting beyond the basal sheath; wall without stomata .... **Notothylas**
Capsule projecting far beyond the basal sheath; wall with distinct stomata .... **Anthoceros**

Notothylas Sull.

Notothylas orbicularis (Schwein.) Sull. *N. valvata* Sull.

On moist soil. Aug.-Nov. LITCHFIELD: Goshen, *Underwood*. NEW HAVEN: Cheshire and East Haven, *Evans;* Hamden (1877) and New Haven, *O. D. Allen;* Orange, *Evans*. MIDDLESEX: Middlefield, *Evans*. NEW LONDON: Norwich, *Setchell*.

New England to Indiana, south to North Carolina; South America (Galapagos Islands); Europe.

EXSIC. Underwood & Cook, Hep. Amer. No. 65.

REF. Eaton, **15**, 69. Evans, **28**, 173. Howe, **48**, 22.

Anthoceros (Mich.) L.

Spores yellow .... **A. levis**
Spores dark brown or black.......................... **A. punctatus**

Anthoceros levis L.

On moist ground and damp or wet rocks. Aug.-Nov. LITCHFIELD: Goshen, *Underwood*. NEW HAVEN: Hamden

(1855), *Eaton;* New Haven, *J. A. Allen;* North Branford, *Evans;* Oxford, *Harger;* Woodbridge, *Eaton.* MIDDLESEX: Cromwell, *Evans.* NEW LONDON: Lisbon, *Mrs. Hadley.*

New England and Ontario, south to the Gulf States and Mexico and west to Iowa; Europe; Asia.

REF. Eaton, **15**, 69. Evans, **28**, 173.

Anthoceros punctatus L.

On damp ground. Aug.-Nov. LITCHFIELD: Goshen, *Underwood.* WINDHAM: Plainfield, *Sheldon.* NEW HAVEN: East Haven, North Branford, and Orange, *Evans;* Oxford, *Harger;* Woodbridge (1879), *J. A. Allen.* MIDDLESEX: Middlefield, *Evans.*

Nova Scotia to Ohio, south to Florida and Louisiana; Europe.

REF. Evans, **28**, 173. Howe, **48**, 16.

[Subclass Musci]

ORDER SPHAGNALES

FAMILY SPHAGNACEÆ

Sphagnum (Dill.) L.

1. Cortical cells of stem and branches without spiral fibrils; branch leaves mostly truncate and toothed or fringed at the apex 2
 Cortical cells of stem and branches with spiral fibrils and pores; branch leaves densely imbricated, cucullate at the apex, not truncate, entire (CYMBIFOLIA, p. 80).......... 28
2. Branches in fascicles of 3-6............................... 3
 Branches in fascicles of 7-14; chlorophyll cells of branch leaves elliptical in cross section and enclosed toward both surfaces of the leaf by the hyaline cells* (POLYCLADA, p. 81)..**S. Wulfianum**
3. Chlorophyll cells mostly triangular to trapezoidal in cross section, either free at both surfaces of the leaf or enclosed toward one leaf surface by the hyaline cells, but always with the base free toward one of the two leaf surfaces 4

* What is said here regarding the form and position of the chlorophyll cells refers always to median cross sections of leaves taken from the middle of one of the spreading branches.

Chlorophyll cells elliptical, spindle-shaped, or rectangular in cross section, not triangular or trapezoidal (except in *S. dasyphyllum*) 20

4. Base toward the inner surface of the leaf; hyaline cells strongly convex toward the outer surface; branch leaves erect (ACUTIFOLIA, p. 83)................................ 5

Base toward the outer surface of the leaf; hyaline cells usually strongly convex toward the inner surface...... 13

5. Stem leaves lacerate-fringed at the broadly rounded apex, without fibrils 6

Stem leaves more or less truncate and toothed at the apex, not fringed 7

6. Stem leaves broadened above, spatulate, apex and upper margins fringed; monoicous ....**S. fimbriatum**

Stem leaves not broadened above, lingulate, fringed only at the apex; dioicous ....**S. Girgensohnii**

7. Stem leaves lingulate, fibrils usually absent, though sometimes present in the upper part of the leaf.............. 8

Stem leaves triangularly lingulate to equilaterally triangular, usually with fibrils 10

8. Plants usually red, never brown........................ 9

Plants usually brown, never red; pores as in *S. Warnstorfii;* stem leaves without fibrils.......................**S. fuscum**

9. Pores present on outer surface of the branch leaves, small, round, and situated in the cell angles; stem leaves without fibrils ....**S. Warnstorfii**

Pores present on outer surface of the lower branch leaves, large, more or less semicircular, and situated along the lateral margins of the cells; stem leaves frequently with fibrils ....**S. rubellum**

10. Branch leaves when dry distinctly 5-ranked; outer wall of cortical cells in stem often with irregular pores in the upper ends of the cells...................**S. quinquefarium**

Branch leaves when dry not arranged in distinct rows.... 11

11. Stem leaves with fibrils and pores; branch leaves not glossy when dry 12

Stem leaves mostly without fibrils or pores; branch leaves glossy when dry; cortical cells of stem seldom with pores; hyaline cells of stem leaves usually 2-6-septate **S. subnitens**

12. Outer wall of cortical cells in stem often with irregular pores in the upper ends of the cells; hyaline cells of stem leaves not divided, or, if so, uniseptate..**S. acutifolium**

Cortical cells in stem without pores; hyaline cells of stem leaves copiously divided by oblique walls.......**S. tenerum**

13. Chlorophyll cells narrowly trapezoidal or rectangular in cross section, free at both surfaces, but with the surface walls strongly thickened (SQUARROSA, p. 81) 14
    Chlorophyll cells with the free walls scarcely, if at all, thickened; branch leaves erect-spreading* (CUSPIDATA, p. 82) 15
14. Plants large, monoicous; branch leaves mostly squarrose from the middle ....**S. squarrosum**
    Plants medium-sized, dioicous; branch leaves more or less imbricated, not squarrose ....**S. teres**
15. Chlorophyll cells triangular in cross section, often enclosed toward the inner leaf surface by the hyaline cells...... 17
    Chlorophyll cells trapezoidal in cross section and free on both surfaces 16
16. Pores numerous on outer surface of the branch leaves, frequently large and usually in rows............**S. Dusenii**
    Pores mostly lacking on outer surface of the branch leaves, when present, small and restricted to the angles of the cells ....**S. cuspidatum**
17. Cortex well differentiated from the central strand........ 18
    Cortex not well differentiated from the central strand.... 19
18. Stem leaves lacerate-fringed at the apex......**S. Pulchricoma**
    Stem leaves toothed at the apex...............**S. Torreyanum**
19. Pores on outer surface of the branch leaves in the apical half restricted to the angles of the cells......**S. recurvum**
    Pores on outer surface of the branch leaves in the apical half occurring in the angles and also along the lateral margins of the cells........................**S. parvifolium**
20. Chlorophyll cells enclosed toward one or both surfaces of the leaf by the hyaline cells, elliptical or spindle-shaped in cross section; branch leaves squarrose from the middle (RIGIDA, p. 81)............................. 21
    Chlorophyll cells free toward both surfaces of the leaf; branch leaves more or less secund or falcate (SUBSECUNDA, p. 85)... 22
21. Chlorophyll cells elliptical in cross section and enclosed toward both leaf surfaces by the hyaline cells...... **S. compactum**
    Chlorophyll cells spindle-shaped in cross section and enclosed toward the inner surface of the leaf by the hyaline cells; the outer wall free, but very strongly thickened ....**S. Garberi**

* *S. dasyphyllum* may be looked for here.

22. Chlorophyll cells trapezoidal in cross section; the walls not thickened, and the broad base toward the outer surface of the leaf; hyaline cells strongly convex toward the inner surface .... **S. dasyphyllum**

Chlorophyll cells barrel-shaped to rectangular in cross section, equally free toward both surfaces, and with the free walls usually thickened 23

23. Cortex of stem consisting of 2-several layers of cells.... 24

Cortex of stem consisting of one layer of cells........... 25

24. Stem leaves small, not more than 1 mm. long, fibrils present only near the apex; branch leaves secund.... **S. contortum**

Stem leaves larger, 1.5-2 mm. long, fibrils usually abundant throughout; branch leaves not secund......**S. platyphyllum**

25. Branch leaves with many pores, at least on the outer surface; pores frequently in bead-like rows............ 26

Branch leaves with very few or no pores.............**S. obesum**

26. Pores few or lacking on the inner surface................ 27

Pores numerous on both surfaces, especially on the outer; stem leaves 1-2 mm. long.....................**S. rufescens**

27. Stem leaves less than 1 mm. long, hyaline cells rarely septate ....**S. subsecundum**

Stem leaves 1-1.5 mm. long, hyaline cells often septate **S. inundatum**

28. Chlorophyll cells of branch leaves usually free toward both surfaces of the leaf............................ 29

Chlorophyll cells of branch leaves enclosed by the hyaline cells, equidistant from both surfaces of the leaf, and elliptical in cross section; hyaline cells smooth or faintly papillose on the lateral walls............**S. medium**

29. Chlorophyll cells triangular or trapezoidal in cross section, the base toward the inner surface of the leaf and not thickened; hyaline cells strongly convex toward the outer surface 30

Chlorophyll cells more or less elliptical in cross section, cell cavity almost central, and both surface walls strongly thickened; hyaline cells more strongly convex toward the outer surface of the leaf than toward the inner surface, and papillose on the lateral walls...... **S. papillosum**

30. Chlorophyll cells broadly triangular to trapezoidal; hyaline cells with irregular bands of thickening on the lateral walls ....**S. imbricatum**

Chlorophyll cells narrowly triangular; hyaline cells smooth on the lateral walls......................**S. cymbifolium**

CYMBIFOLIA

Sphagnum imbricatum Hornsch.

HARTFORD: Canton, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Thompson, *Miller.* NEW HAVEN: East Haven and New Haven (1891), *Evans.* NEW LONDON: Voluntown, *Miller.*

Var. **affine** (Ren. & Card.) Warnst.

LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven (1875), *Eaton;* Hamden, New Haven, North Haven, Orange, and Woodbridge, *Evans.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Var. **subleve** Warnst.

LITCHFIELD: Salisbury, *Nichols.* NEW HAVEN: New Haven (1891), *Evans.*

Newfoundland and Labrador to Alaska, south to Louisiana; Europe; Asia.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. No. 154 (var. *affine*).

REF. Andrews, 1, 62.

Sphagnum cymbifolium Ehrh.

LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Ellington, *Pease.* FAIRFIELD: Norwalk, *Harger.* NEW HAVEN: Bethany and Branford, *Eaton;* East Haven and Hamden, *Evans;* New Haven (1878), *Eaton;* Oxford, *Harger.* NEW LONDON: Waterford, *Miss Lorenz.*

Var. **squarrosulum** Nees & Hornsch.

NEW HAVEN: Branford, *Eaton;* East Haven (1891), *Evans;* Hamden, *Eaton.*

Newfoundland and Labrador to Alaska, south to Florida and British Columbia; a cosmopolitan.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 156, 157 (var. *glaucescens*), 160, and 161 (var. *pallescens*).

REF. Andrews, 1, 62. Eaton, 15, 68.

Sphagnum papillosum Lindb.

TOLLAND: Stafford, *Nichols.* NEW HAVEN: East Haven (1891), *Evans.*

Newfoundland and Labrador to Alaska, south to Alabama and Washington; Europe.

Sphagnum medium Limpr.

LITCHFIELD: Salisbury, *Nichols*. TOLLAND: Stafford, *Nichols*. WINDHAM: Thompson, *Miller*. NEW HAVEN: Bethany, Hamden, and New Haven (1890), *Evans;* Oxford, *Harger*. NEW LONDON: Ledyard, *C. B. Graves*.

Newfoundland and Labrador to Alaska, south to Florida; South America; Europe; Asia.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 166 (var. *roseum*), 167 (var. *purpurascens*), and 168 (var. *versicolor*).

REF. Andrews, 1, 63.

RIGIDA

Sphagnum compactum DC.

In wet woods. NEW HAVEN: Beacon Falls (1907), *Nichols*.

Arctic America, Canada, and the northern United States; Europe; Asia; Madeira Islands.

Sphagnum Garberi Lesq. & James var. **squarrosulum** Warnst.

NEW HAVEN: Naugatuck (1905), *Evans*.

Newfoundland to Florida; Europe.

POLYCLADA

Sphagnum Wulfianum Girgens.

In swampy woods. LITCHFIELD: Salisbury (1907), *Nichols;* Winchester, *Miss Lorenz*.

Greenland to Connecticut, westward to the Rocky Mountains; Europe; Asia.

SQUARROSA

Sphagnum squarrosum Pers. var. **spectabile** Russ.

Deep wooded swamps. LITCHFIELD: Salisbury (1907), *Nichols*.*

* *S. squarrosum* was reported from Hamden by Hall in the Berzelius List (Eaton, **15**, 68), but the specimens have been lost sight of.

Arctic America, Canada, and the northern United States; Europe; Asia; Azores.

Sphagnum teres (Schimp.) Aongstr.

TOLLAND: Bolton (1906), *Nichols.* NEW HAVEN: Cheshire, *Nichols.*

Arctic America, Canada, and the northern United States; Europe; Asia.

CUSPIDATA

Sphagnum Pulchricoma C. Müll.

NEW LONDON: Ledyard (1884), *C. B. Graves;* Voluntown, *Miller.*

Connecticut to Florida and Louisiana; South America; Africa.

Sphagnum Torreyanum Sull. *S. cuspidatum* var. *Torreyanum* Braithw. and var. *miquelonense* Ren. & Card.

NEW HAVEN: Branford (1891), *Evans.* NEW LONDON: Voluntown, *Miller.*

REF. Andrews, 1, 62.

Sphagnum recurvum Beauv.

LITCHFIELD: Salisbury, *Nichols;* Woodbury, *Harger.* NEW HAVEN: East Haven and Hamden (1891), *Evans;* Oxford, *Harger.*

Var. **amblyphyllum** (Russ.) Warnst.

LITCHFIELD: Salisbury, *Nichols.* NEW HAVEN: Bethany, *Evans;* East Haven, *Eaton;* Hamden (1880), *J. A. Allen.*

Newfoundland and Labrador to Alaska, south to the Gulf of Mexico; a cosmopolitan.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 104 (var. *mucronatum*) and 107 (var. *amblyphyllum*). Warnstorf, Eur. Torfm. Serie IV, No. 263 (var. *mucronatum*).

REF. Andrews, 1, 63.

Sphagnum parvifolium (Sendt.) Warnst.

LITCHFIELD: Salisbury (1907), *Nichols.*

Probably has the same range as *S. recurvum.*

Sphagnum Dusenii C. Jens.

LITCHFIELD: Salisbury (1907), *Nichols.*

Newfoundland and Quebec to Connecticut and New York; Europe; Asia.

Sphagnum cuspidatum Ehrh.

Frequently submerged. LITCHFIELD: Salisbury, *Nichols;* Woodbury, *Harger.* NEW HAVEN: Bethany, *Eaton;* East Haven, *Evans;* Hamden (1880), *O. D. Allen;* Oxford, *Harger.*

Var. **falcatum** Russ.

NEW HAVEN: Bethany and Hamden (1892), *Evans.*

Var. **plumosum** Nees & Hornsch.

NEW HAVEN: Bethany and Hamden (1891), *Evans.*

Newfoundland to the Gulf of Mexico; a cosmopolitan.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 93 (var. *falcatum*), 96 (var. *submersum*), and 97 (var. *plumosum*).

REF. Andrews, 1, 62.

ACUTIFOLIA

Sphagnum fimbriatum Wils.

NEW HAVEN: Hamden (1891), *Evans.*

Arctic America, Canada, and the northern United States; South America; Europe; Asia.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. No. 11 (var. *tenue*).

REF. Andrews, 1, 62.

Sphagnum Girgensohnii Russ.

LITCHFIELD: Norfolk (1875), *Eaton;* Salisbury, *Nichols.* NEW HAVEN: Hamden, *O. D. Allen.*

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Andrews, 1, 62. Cardot, 11, 305.

Sphagnum rubellum Wils. *S. tenellum* (Schimp.) Klinggr.

LITCHFIELD: Salisbury, *Nichols.* NEW HAVEN: Bethany (1892), *Evans;* Oxford, *Harger.*

Newfoundland and Labrador to Connecticut, westward to Alaska; Europe.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 29 and 31 (var. *versicolor*).

REF. Andrews, **1**, 63. Cardot, **11**, 409. Eaton, **18**, 3.

Sphagnum Warnstorfii Russ.

LITCHFIELD: Salisbury, *Nichols*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Hamden (1891), *Evans;* Middlebury, *Harger*.

Newfoundland to Connecticut, westward to the Pacific: Europe.

REF. Andrews, 1, 63. Cardot, **11**, 419.

Sphagnum fuscum (Schimp.) Klinggr.

NEW HAVEN: New Haven (1893), *Eaton*.

Canada and the northern United States; Europe.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. No. 35.

REF. Andrews, **1**, 62. Eaton, **18**, 3.

Sphagnum quinquefarium (Lindb.) Warnst.

NEW HAVEN: Hamden and New Haven (1890), *Evans*.

Newfoundland to Connecticut, and southward along the Alleghany Mountains; Europe.

REF. Cardot, **11**, 366. Eaton, **18**, 3.

Sphagnum subnitens Russ. & Warnst.

NEW HAVEN: Hamden (1891), *Evans;* New Haven, *Eaton*.

Var. **flavicomans** (Card.) Warnst.

NEW HAVEN: Bethany, East Haven (1891), and New Haven, *Evans*.

Newfoundland to New Jersey; Alaska; Azores; Europe; Asia; the variety found only in North America.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 51 (var. *flavicomans*) and 54 (var. *obscurum*).

REF. Andrews, 1, 63 (var. *flavicomans*). Cardot, **11**, 399.

Sphagnum tenerum (Aust.) Warnst.

New Haven: East Haven and Hamden (1891), *Evans;* New Haven, *Eaton.*

Newfoundland to New Jersey; Europe.

Exsic. Eaton & Faxon, Sphag. Bor.-Amer. No. 60. Warnstorf, Eur. Torfm. Serie IV, No. 363.

Ref. Andrews, **1**, 63. Cardot, **11**, 410.

Sphagnum acutifolium Ehrh.

Litchfield: Salisbury, *Mrs. Phelps.* Hartford: Canton, *Nichols.* Tolland: Stafford, *Nichols.* New Haven: Bethany, *Eaton;* Branford, East Haven, and Hamden, *Evans;* New Haven (1865), *Eaton;* Oxford, *Harger.*

Throughout North America; Europe.

Exsic. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 40 (var. *rubrum*), 44 (var. *versicolor*), 48 (var. *viride*), and 50 (var. *roseum*).

Ref. Andrews, **1**, 62.

SUBSECUNDA

Sphagnum dasyphyllum Warnst.

New Haven: New Haven (1891), *Evans.* This is the only known locality.

Exsic. Warnstorf, Eur. Torfm. Serie IV, No. 338.

Ref. Andrews, **1**, 62. Cardot, **11**, 287. Eaton, **18**, 7. Paris, **61**, 1189; **62**[4], 273. Renauld & Cardot, **65**, 68. Warnstorf, **78**, 176.

Sphagnum obesum (Wils.) Warnst.

Usually submerged or floating. Litchfield: Woodbury, *Harger.* New Haven: Branford (1891) and Hamden, *Evans;* Oxford, *Harger;* Woodbridge, *Evans.*

New Hampshire to Virginia; Europe.

Exsic. Eaton & Faxon, Sphag. Bor.-Amer. No. 127.

Ref. Andrews, **1**, 63. Cardot, **11**, 344. Paris, **62**[4], 289.

Sphagnum contortum Schultz. *S. laricinum* Spruce.

Litchfield: Woodbury, *Harger.* New Haven: New Haven (1891), North Branford, and Orange, *Evans;* Oxford, *Harger;* Prospect, *Eaton;* Woodbridge, *Evans.*

Massachusetts to Pennsylvania and probably southward; Europe.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. No. 141.

REF. Andrews, 1, 62. Cardot, 11, 320.

Sphagnum platyphyllum (Lindb.) Warnst.

NEW HAVEN: New Haven (1891), *Evans*.

Massachusetts to Ohio; Europe.

REF. Andrews, 1, 63.

Sphagnum subsecundum Nees.

TOLLAND: Ellington (1876), *Pease*. WINDHAM: Thompson, *Miller*. FAIRFIELD: Danbury, *Nichols*. NEW HAVEN: Branford, Cheshire, East Haven, Hamden, and Orange, *Evans;* Oxford, *Eaton*.

Newfoundland to Ohio and Alabama; Europe; Asia.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 130 (var. *macrophyllum*) and 134 (var. *mesophyllum*).

REF. Andrews, 1, 63.

Sphagnum inundatum Russ.

LITCHFIELD: Salisbury, *Nichols*. TOLLAND: Stafford, *Nichols*. FAIRFIELD: Stratford (1906), *Nichols*. MIDDLESEX: Killingworth, *Nichols*.

Range probably the same as that of *S. subsecundum*.

Sphagnum rufescens (Nees & Hornsch.) Warnst.

Frequently submerged. NEW HAVEN: Hamden (1891) and New Haven, *Evans;* Oxford, *Eaton;* Woodbridge, *Evans*.

Newfoundland and Labrador to Alabama; Europe.

EXSIC. Eaton & Faxon, Sphag. Bor.-Amer. Nos. 142 and 143.

REF. Andrews, 1, 63. Eaton, 18, 7.

ORDER ANDREÆALES

FAMILY ANDREÆACEÆ

Andreæa Ehrh.

Midrib present .... **A. Rothii**
Midrib wanting .... **A. petrophila**

Andreæa petrophila Ehrh.

On non-calcareous rocks in mountainous or hilly regions. Summer. HARTFORD: Bloomfield, *Miss Lorenz*. NEW HAVEN: Meriden, *Miss Lorenz;* Woodbridge (1878), *J. A. Allen.*

Arctic America, Canada, and the northern United States; South America; Europe; Asia; Tasmania; New Zealand.

Andreæa Rothii Web. f. & Mohr.

On non-calcareous rocks in mountainous or hilly regions. Summer. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: Beacon Falls, *Evans;* Branford, *Eaton;* Oxford, *Harger;* Woodbridge (1887), *Setchell.*

Newfoundland to Alabama and Tennessee; Greenland; Europe.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 153.

ORDER BRYALES

Sporophyte borne at the apex of the stem or of a more or less elongated branch............ACROCARPI, p. 87
Sporophyte borne on a very short branch..PLEUROCARPI, p. 91

[ACROCARPI]

1. Capsule almost never opening by means of a lid.......... 2
   Capsule opening by means of a clearly defined lid........ 8
2. Green protonema persistent; plants fruiting in autumn.... **Ephemerum**, p. 116
   Green protonema not persistent; plants fruiting in spring 3
3. Spores few (16-20) and very large, sometimes 0.2 mm. in diameter ....**Archidium**, p. 95
   Spores numerous and small, rarely more than 0.05 mm. in diameter 4
4. Leaf margins plane or involute........................... 5
   Leaf margins more or less revolute...................... 7
5. Capsule pyriform ....**Bruchia**, p. 95
   Capsule ovoid-globose 6
6. Leaves smooth ....**Pleuridium**, p. 96
   Leaves papillose; a rudimentary lid present but persistent **Astomum**, p. 106

7. Leaves smooth, eroso-denticulate at the apex........ **Acaulon,** p. 108
Leaves papillose, entire ....**Phascum,** p. 108

8. Peristome, when present, with articulate teeth........... 9
Peristome teeth not articulate........................... 53

9. Peristome present 10
Peristome none 48

10. Leaves in 2 ranks, clasping at the base, and with a prominent dorsal wing 11
Leaves in 3 or more ranks, not clasping at the base or winged 12

11. Plants flaccid, aquatic, floating ....**Octodiceras,** p. 105
Plants not flaccid, sometimes submerged, but not floating **Fissidens,** p. 103

12. Leaves with a single layer of small chlorophyll cells enclosed by two or more layers of large hyaline cells **Leucobryum,** p. 102
Leaves mostly with a single layer of uniform cells........ 13

13. Peristome single, consisting of 16 or 32 teeth; teeth usually without a median longitudinal line on the outer surface 14
Peristome double, the outer more or less thickened and consisting of 16 teeth, the inner thin and divided into segments or cilia or both; teeth with a distinct median longitudinal line on the outer surface.................. 33

14. Capsule with 8 longitudinal ridges of differentiated cells **Rhabdoweisia,** p. 99
Capsule smooth or, when plicate, the epidermis of uniform cell structure 15

15. Peristome teeth with very minute longitudinal striations on the outer surface.................................. 16
Peristome teeth without longitudinal striations on the outer surface, smooth or papillose..................... 19

16. Alar cells large, hyaline or brown...................... 17
Alar cells not differentiated............................ 18

17. Leaves tufted; capsule distinctly strumose; monoicous.. **Oncophorus,** p. 99
Leaves regularly secund; capsule not strumose or obscurely so; dioicous ....**Dicranum,** p. 100

18. Lamina of leaves strongly papillose.....**Dichodontium,** p. 99
Lamina of leaves smooth...................**Dicranella,** p. 98

19. Peristome distinctly twisted, teeth 32.................... 20
Peristome not twisted, teeth 16, often deeply cleft........ 22

20. Midrib with 2 median guides, upper band of stereid cells lacking .... **Tortula**, p. 109
Midrib with several (4-8) median guides and 2 bands of stereid cells 21

21. Leaf margins revolute, at least below the middle...... **Barbula**, p. 108
Leaf margins plane, not revolute............. **Tortella**, p. 107

22. Calyptra mitrate 23
Calyptra cucullate 27

23. Calyptra plicate 24
Calyptra not plicate 25

24. Calyptra smooth; teeth distantly articulate................ **Glyphomitrium**, p. 110
Calyptra hairy; teeth closely articulate... **Orthotrichum**, p. 113

25. Beak long, clavate .... **Encalypta ciliata**, p. 110
Beak apiculate to aciculate 26

26. Teeth narrowly cleft nearly to the base.. **Racomitrium**, p. 112
Teeth subentire, cribrose or irregularly cleft.. **Grimmia**, p. 111

27. Teeth of peristome arising from a distinct basal membrane 28
Teeth of peristome not arising from a basal membrane.... 31

28. Teeth short; leaves papillose on upper surface............ **Didymodon**, p. 108
Teeth long; leaves mostly smooth....................... 29

29. Capsule inclined, distinctly plicate when dry; leaf cells roundish quadrate above .... **Ceratodon**, p. 97
Capsule erect, smooth or slightly plicate when dry; leaf cells more or less elongated above.................... 30

30. Leaves glaucous .... **Saelania**, p. 97
Leaves bright or dark green, glossy........ **Ditrichum**, p. 96

31. Plants growing on trees................. **Drummondia**, p. 113
Plants growing on earth or rocks....................... 32

32. Leaf margins strongly involute above, entire... **Weisia**, p. 106
Leaf margins plane, minutely crenulate.. **Trichostomum**, p. 107

33. Inner peristome without a basal membrane............... 34
Inner peristome with a distinct carinate basal membrane.. 37

34. Calyptra cucullate .... **Funaria**, p. 117
Calyptra mitrate 35

35. Calyptra not plicate, smooth, entirely enclosing and extending below the base of the capsule............ **Encalypta contorta**, p. 110
Calyptra plicate, usually hairy and partially enclosing the capsule 36

36. Leaves usually crispate when dry, base oval; stomata in neck of capsule, always superficial............**Ulota,** p. 115
Leaves not crispate when dry, base not oval; stomata in neck and upper part of capsule, mostly immersed......
Orthotrichum, p. 113

37. Capsule distinctly ribbed when dry....................... 38
Capsule smooth, not ribbed when dry.................... 41

38. Capsule ovoid-cylindrical ....**Aulacomnium,** p. 125
Capsule subglobose 39

39. Cilia well developed........................**Philonotis,** p. 127
Cilia none, or very rudimentary.......................... 40

40. Leaf cells smooth ....**Plagiopus,** p. 126
Leaf cells papillose ....**Bartramia,** p. 127

41. Leaves papillose on upper surface.............**Timmia,** p. 127
Leaves smooth 42

42. Inner peristome 2-3 times as long as the outer, cilia rudimentary ....**Meesea,** p. 126
Inner peristome about as long as the outer, cilia well developed 43

43. Cilia appendiculate 44
Cilia smooth or nodose, not appendiculate............... 46

44. Leaf cells narrow, linear-rhomboidal above..............
Leptobryum, p. 117
Leaf cells rhomboidal-hexagonal, never linear........... 45

45. Plants stoloniferous; capsules clustered...**Rhodobryum,** p. 120
Plants not stoloniferous; capsules borne singly..**Bryum,** p. 119

46. Upper leaves ovate; cells broadly polygonal, never linear
Mnium, p. 121
Upper leaves linear-lanceolate; cells narrowly polygonal to linear above 47

47. Leaves glaucous green; annulus none.....**Mniobryum,** p. 118
Leaves green to golden yellow, often glossy; annulus present ....**Pohlia,** p. 118

48. Plants growing on rocks or in crevices.................. 49
Plants growing on earth................................ 51

49. Leaves without a midrib; stalk less than 1 mm. long; lid apiculate ....**Hedwigia,** p. 128
Leaves with a midrib; stalk 2-10 mm. long; lid rostrate.... 50

50. Usually growing on calcareous rocks; capsule smooth
Hymenostylium, p. 106
Usually growing on non-calcareous rocks; capsule ribbed
Anœctangium, p. 112

51. Leaf cells isodiametric above the middle; calyptra cucullate ....**Pottia,** p. 109
Leaf cells elongated above the middle; calyptra mitrate 52

52. Stalk almost lacking..................**Aphanorrhegma,** p. 117
Stalk long (to 2 cm.)..................**Physcomitrium,** p. 117

53. Capsule symmetrical or nearly so........................ 54
Capsule strikingly unsymmetrical 57

54. Teeth of peristome 4..........................**Georgia,** p. 172
Teeth of peristome 32 or 64.............................. 55

55. Calyptra cucullate, nearly smooth..........**Catharinæa,** p. 172
Calyptra mitrate, densely hairy............................ 56

56. Capsule without stomata, cylindrical......**Pogonatum,** p. 174
Capsule with stomata, prismatic or cylindrical..........
Polytrichum, p. 174

57. Capsule sessile; leaves green and conspicuous..**Webera,** p. 171
Capsule raised on a thick, red stalk; leaves colorless and very minute ....**Buxbaumia,** p. 172

[PLEUROCARPI]

1. Leaves distichous ....**Fissidens,** p. 103
Leaves in 3 or more ranks.............................. 2

2. Segments of inner peristome rudimentary or filiform, not split; cilia none 3
Segments of inner peristome distinctly carinate, often split along the keel 10

3. With a distinct, carinate basal membrane, segments very rudimentary; leaves papillose.................**Thelia,** p. 135
Without a basal membrane; leaves smooth or nearly so.. 4

4. Segments connected, at least in the apical region, by transverse bands 5
Segments entirely free, sometimes very rudimentary...... 6

5. Leaves with an excurrent midrib...........**Dichelyma,** p. 130
Leaves without a midrib....................**Fontinalis,** p. 128

6. Leaves complanate, transversely undulate.....**Neckera,** p. 131
Leaves spreading, not transversely undulate.............. 7

7. Plants soft, often forming wide, velvety tufts; capsule strikingly contracted below the mouth when dry......
Anacamptodon, p. 134
Plants coarse, growing in lax, frequently pendent tufts; capsule not contracted below the mouth when dry...... 8

8. Leaves with a midrib.................................... 9
Leaves without a midrib...................**Leucodon,** p. 130

9. Branches terete; capsule immersed.......... **Cryphæa,** p. 130
Branches flattened; capsule emergent on a short stalk.... **Forrstroemia,** p. 131

10. Leaves mostly rough-papillose.......................... 11
Leaves smooth, rarely slightly papillose at the cell angles. 21

11. Capsule symmetrical, erect or nearly so.................. 12
Capsule unsymmetrical, arcuate 16

12. Leaves with a midrib, margin usually entire.............. 13
Leaves without a midrib 15

13. Midrib extending nearly to apex of leaf................ 14
Midrib vanishing at middle of leaf or below.............. **Haplohymenium,** p. 136

14. Primary stem stoloniform; stem leaves minute.......... **Anomodon,** p. 137
Stem not stoloniform; stem and branch leaves uniform **Leskea,** p. 138

15. Plants glaucous green, branches julaceous; leaves closely imbricated; cilia two...................... **Myurella,** p. 136
Plants light green, branches slightly flattened; leaves loosely appressed; cilia none.... **Schwetschkeopsis,** p. 132

16. Monoicous 17
Dioicous 20

17. Stem and branch leaves differing in size and shape; leaf cells with several minute papillæ...................... 18
Stem and branch leaves similar in size and shape; leaf cells with one, rarely two papillæ, or smooth.......... 19

18. Lid short-rostrate; paraphyllia multiform...... **Rauia,** p. 139
Lid long-rostrate; paraphyllia simple........ **Thuidium,** p. 140

19. Leaf cells smooth or lightly papillate; plants of swampy woods or meadows......................... **Elodium,** p. 142
Leaf cells strongly papillate on both surfaces; plants of moist woods .... **Haplocladium,** p. 139

20. Stem and branch leaves similar in size and shape; paraphyllia mostly lacking.................. **Claopodium,** p. 140
Stem and branch leaves differing in size and shape; paraphyllia numerous .... **Thuidium,** p. 140

21. Stem erect from a creeping caudex, dendroid; capsules clustered 22
Stem prostrate or ascending; capsules borne singly...... 23

22. Cilia lacking .... **Climacium,** p. 170
Cilia well developed, appendiculate......... **Thamnium,** p. 171

23. Capsule symmetrical, erect or nearly so; inner peristome without cilia 24
Capsule unsymmetrical, more or less inclined and curved; inner peristome arising from a broad basal membrane; cilia well developed 29

24. Branches strongly complanate; leaves cultriform........ **Homalia,** p. 132
Branches terete or somewhat flattened; leaves ovate to **lanceolate** 25

25. Segments either partially or wholly lining the teeth, basal membrane lacking or obscure.......... 26
Segments entirely free from the teeth.......... 27

26. Leaves with a midrib; stalk rough....**Homalothecium,** p. 134
Leaves without a midrib; stalk smooth.......**Pylaisia,** p. 133

27. Basal membrane broad and distinct.......... **Pylaisia subdenticulata,** p. 134
Basal membrane very narrow, or lacking.......... 28

28. Stem oval in cross-section; capsule 3-4 mm. long........ **Entodon,** p. 132
Stem round in cross-section; capsule 1.5-2.5 mm. long; annulus several cells broad..........**Platygyrium,** p. 132

29. Midrib single 30
Midrib double or furcate, frequently short or lacking...... 42

30. Lid more or less long-rostrate.......... 31
Lid conical to short-rostrate.......... 33

31. Leaves spreading or imbricated.......... 32
Leaves complanate ....**Rhynchostegium,** p. 150

32. Leaves very concave, spoon-shaped, abruptly filiform-acuminate ....**Cirriphyllum,** p. 147
Leaves plane or slightly concave, acute or gradually acuminate ....**Eurynchium,** p. 148

33. Leaves obtuse, apiculate, or acute.......... 34
Leaves acuminate 36

34. Large mosses (6-20 cm.), growing in swamps; stem leaves 2-3.5 mm. long, spreading or imbricated...**Calliergon,** p. 166
Medium-sized mosses (3-8 cm.), growing on rocks and earth in or along streams; leaves 0.6-1.6 mm. long, frequently secund 35

35. Midrib strong, disappearing abruptly just below apex of leaf ....**Amblystegium fluviatile,** p. 157
Midrib faint, vanishing near middle of leaf, frequently forked ....**Hygrohypnum,** p. 169

36. Leaves secund 37
Leaves equally spreading 39

37. Leaves strongly transversely undulate.....**Rhytidium,** p. 160
Leaves not transversely undulate........................ 38

38. Paraphyllia numerous ....**Cratoneuron,** p. 159
Paraphyllia lacking ....**Drepanocladus,** p. 167

39. Capsule oblong-ovoid; stem leaves much larger than branch leaves ....**Brachythecium,** p. 143
Capsule oblong-cylindrical; leaves mostly uniform in size 40

40. Stem densely tomentose, erect; leaves glossy............ **Camptothecium,** p. 142
Stem not densely tomentose; leaves rarely glossy......... 41

41. Stem prostrate and irregularly branched; rhizoids mostly numerous ....**Amblystegium,** p. 155
Stem prostrate or ascending; rhizoids few................ **Chrysohypnum,** p. 158

42. Leaves complanate 43
Leaves not complanate 44

43. Leaves decurrent; basal areolation lax, alar cells often more or less enlarged................**Plagiothecium,** p. 152
Leaves not at all or very slightly decurrent; basal cells scarcely differentiated ....**Isopterygium,** p. 151

44. Operculum long-rostrate ....**Sematophyllum,** p. 150
Operculum conical to short-rostrate...................... 45

45. Leaves obtuse or apiculate, rarely acute.................. 46
Leaves acuminate 48

46. Leaves usually more or less secund, gradually narrowed above to an obtuse or rarely acute apex; mosses growing on dripping or wet rocks.............**Hygrohypnum,** p. 169
Leaves imbricated or spreading, with a broad rounded apex 47

47. Mosses growing in swamps; stem with an outer layer of large hyaline cells ....**Acrocladium,** p. 167
Mosses growing in dry woods; stem bright red, cortical cells small ....**Hypnum,** p. 166

48. Leaves secund, falcate or circinate...................... 49
Leaves mostly spreading 51

49. A large moss (8-20 cm.), very regularly pinnate, frondiform; leaves multiplicate, smooth; paraphyllia numerous **Ptilium,** p. 162
Medium-sized mosses (1-10 cm.), irregularly pinnate; leaves scarcely or not at all plicate; paraphyllia few or none 50

50. Leaves sharply serrate, papillose............**Ctenidium,** p. 161
Leaves entire or serrulate, smooth..........**Stereodon,** p. 162

51. Alar cells inflated............**Plagiothecium striatellum,** p. 154
Alar cells not inflated, frequently quadrate, rectangular, or oblong 52

52. Annual growth regularly marked off......**Hylocomium,** p. 161
Annual growth not clearly defined........................ 53

53. Leaves erect-spreading 54
Leaves squarrose 55

54. Plants medium-sized, forming loose, spreading tufts; paraphyllia numerous and large...........**Heterophyllon,** p. 165
Plants small, forming thin, depressed mats; paraphyllia lacking ....**Amblystegiella,** p. 154

55. Plants robust; stems 0.5-0.9 mm. in diameter; leaves 3-5 mm. long; capsules broadly ovoid........**Rhytidiadelphus,** p. 160
Plants robust or slender; stems 0.1-0.4 mm. in diameter; leaves 1-3 mm. long; capsules cylindrical..............
Chrysohypnum, p. 158

FAMILY ARCHIDIACEÆ

Archidium Brid.

Archidium ohioense Schimp.

On the ground in meadows and fields. Spring. New Haven: Orange (1881), *O. D. Allen.*

Throughout the eastern United States and westward to the Rocky Mountains.

FAMILY DICRANACEÆ

Bruchia Schwaegr.

Capsule ovoid, neck short.........................**B. flexuosa**
Capsule elongated, neck long...................**B. Sullivantii**

Bruchia flexuosa (Schwaegr.) C. Müll.

Clayey ground in fields. Spring. Windham: Canterbury, *Mrs. Hadley.* New Haven: East Haven, *Nichols;* New Haven (1878), *J. A. Allen;* Woodbridge, *Eaton.*

New England to Minnesota, south to the Gulf States.

Ref. Eaton, 15, 72.

Bruchia Sullivantii Aust.

Clayey or sandy ground in fields. Spring. New Haven: New Haven (1890), *Evans.*

New England to Florida, west to Missouri and Louisiana.

Pleuridium Brid.

Leaves spreading, upper leaves long-subulate..**P. alternifolium**
Leaves of sterile shoots closely appressed, upper leaves of fertile shoots abruptly short-pointed..........**P. Sullivantii**

Pleuridium alternifolium (Dicks.) Rabenh.

Moist clayey or sandy soil in fields and ditches. Spring. NEW HAVEN: East Haven, *J. A. Allen;* Hamden and New Haven (1874), *Eaton.*

New England to Wisconsin, south to the mountains of Alabama; Europe; Asia.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 227.

REF. Eaton, **15,** 61.

Pleuridium Sullivantii Aust.

Light, sandy soil in fields. Spring. NEW HAVEN: Orange (1880), *O. D. Allen.*

Connecticut to South Carolina.

Ditrichum Timm

1. Monoicous; stalk yellow; fruiting in June.........**D. pallidum**
   Dioicous; stalk red; fruiting in autumn.................. 2
2. Stem leaves imbricated; perichætial leaves long-sheathing **D. vaginans**
   Stem leaves spreading; perichætial leaves scarcely sheathing ....**D. tortile**

Ditrichum vaginans (Sull.) Hampe. *Leptotrichum vaginans* Schimp.

Moist, sandy or loamy ground in hilly regions. Autumn. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Hamden, *O. D. Allen;* New Haven (1855), *Eaton.*

New Brunswick to North Carolina, west to Missouri; Europe.

REF. Eaton, **15,** 62.

Ditrichum tortile (Schrad.) Lindb. *Leptotrichum tortile* C. Müll.

Clayey soil along roadsides and in fields. Autumn. HARTFORD: Glastonbury, *Miss Lorenz.* TOLLAND: Bolton and

Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, *Nichols.* NEW HAVEN: Hamden, *Evans;* Meriden, *Nichols;* New Haven (1855), *Eaton;* Orange, *Nichols.* MIDDLESEX: Chester, *Nichols.* NEW LONDON: Waterford, *C. B. Graves.*

Newfoundland and Labrador to Minnesota, south to the Gulf States; Europe; Asia; Africa.

REF. Eaton, **15**, 62.

Ditrichum pallidum (Schreb.) Hampe. *Leptotrichum pallidum* Hampe.

Bare earth in the woods. June. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Southington, *Chamberlain.* TOLLAND: Andover, *Weatherby;* Bolton, *Miss Lorenz.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Sherman and Stratford, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven, *Evans;* Hamden (1867), New Haven, and North Haven, *Eaton;* Orange, *Nichols;* Woodbridge, *J. A. Allen.* NEW LONDON: Ledyard and North Stonington, *C. B. Graves.*

Ontario to the Gulf of Mexico, west to Kansas; Europe; Asia; Africa.

REF. Eaton, **15**, 62.

Saelania Lindb.

Saelania glaucescens (Hedw.) Broth. *S. cæsia* (Vill.) Lindb.

Earth and crevices of rocks, especially limestone, in mountainous or hilly regions. Summer. LITCHFIELD: Salisbury, *Evans.* FAIRFIELD: Monroe, *Miss Lorenz;* Sherman, *Nichols.* NEW HAVEN: New Haven (1878), *J. A. Allen;* Oxford, *Miss Lorenz.*

Greenland and Labrador to the Middle Atlantic States, west to British Columbia and Colorado; Europe; Asia; New Zealand.

Ceratodon Brid.

Ceratodon purpureus (L.) Brid.

Burnt-over woods, roadsides, waste ground, and roofs. May-June. LITCHFIELD: New Milford, *Nichols;* Salisbury,

Mrs. Phelps. HARTFORD: Bloomfield and Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Bridgeport, *Eames;* Darien, *Mrs. Lowe;* Fairfield, *Eames;* Huntington, *Nichols.* NEW HAVEN: Cheshire and Madison, *Nichols;* New Haven (1855), *Eaton;* North Haven, *J. A. Allen;* Orange, *Evans;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* Waterford, *C. B. Graves.*

Throughout North America; a cosmopolitan.

REF. Eaton, **15**, 62. Mrs. Lowe, **54** (incorrectly determined as *C. minor* Aust.).

Dicranella Schimp.

1. Capsule plicate when dry; epidermis composed of narrow cells; stalk yellowish........................**D. heteromalla**
   Capsule always smooth; epidermis composed of quadrate cells; stalk reddish 2
2. Capsule cernuous ....**D. varia**
   Capsule erect ....**D. rufescens**

Dicranella heteromalla (L.) Schimp. *Dicranum heteromallum* Hedw.

Clayey, non-calcareous soil in open woods. Autumn. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Southington, *Chamberlain.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, *Nichols.* NEW HAVEN: East Haven (1877) and Hamden, *J. A. Allen;* Madison, *Nichols;* New Haven, *O. D. Allen;* Orange, *J. A. Allen;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: East Lyme and New London, *C. B. Graves.*

Newfoundland to Louisiana, westward to the Pacific; Europe; Asia.

REF. Eaton, **15**, 61.

Dicranella rufescens (Dicks.) Schimp.

Wet clayey soil. Autumn. HARTFORD: Wethersfield, *Mrs. Lowe.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: New Haven (1879), *J. A. Allen;* Woodbridge, *Eaton.*

Nova Scotia to West Virginia, west to Alaska and Washington; Europe; Asia.

REF. Mrs. Lowe, **57**.

Dicranella varia (Hedw.) Schimp. *Dicranum varium* Hedw.

Clay banks and moist earth. Autumn. NEW HAVEN: East Haven, *O. D. Allen;* New Haven (1875), *J. A. Allen;* Orange, *Young;* Oxford, *Harger;* Woodbridge, *J. A. Allen.*

Nova Scotia to Georgia, westward to the Pacific; Alaska; Europe; Asia; Africa.

REF. Eaton, **15**, 61.

Rhabdoweisia Br. & Sch.

Rhabdoweisia denticulata (Brid.) Br. & Sch.

Moist shaded cliffs, steep rocks and banks, but not on limestone, in mountainous or hilly regions. Summer. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* TOLLAND: Stafford and Vernon, *Nichols.* FAIRFIELD: Redding, *Evans;* Sherman, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Naugatuck, *Evans;* New Haven, *O. D. Allen;* Woodbridge (1878), *J. A. Allen.*

Newfoundland to Wisconsin and North Carolina; Europe.

Dichodontium Schimp.

Dichodontium pellucidum (L.) Schimp.

Banks of streams and wet rocks in the woods. Autumn. NEW HAVEN: Hamden (1881), *J. A. Allen.*

Arctic America, Canada, and the northern United States; Europe; Asia.

Oncophorus Brid.

Oncophorus virens (Sw.) Brid. *Cynodontium virens* Schimp.

Moist non-calcareous earth and rocks or damp wood in mountainous or hilly woods. Spring. TOLLAND: Stafford (1906), *Nichols.*

Canada and the northern United States; Europe; Asia.

Dicranum Hedw.

1. **Capsule cernuous, arcuate** **2**
   Capsule erect, symmetrical **5**

2. **Leaves not undulate, midrib percurrent**..........**D. scoparium**
   Leaves transversely undulate, midrib not reaching apex.... 3

3. Upper leaf cells elongated; capsules clustered...**D. undulatum**
   Upper leaf cells isodiametric; capsules borne singly....... 4

4. **Upper part of leaves strongly papillose at back**....**D. spurium**
   Leaves smooth at back............................**D. Bergeri**

5. **Lamina of leaves more or less bistratose in upper part**.... **D. fulvum**
   Lamina unistratose throughout **6**

6. Midrib without median guides and excurrent; leaves suddenly narrowed into a long setaceous point..**D. longifolium**
   Midrib with median guides and vanishing below apex of leaf; leaves lanceolate-subulate 7

7. Cells in upper part of leaves rectangular, papillose at back; plants not producing flagelliform branchlets..**D. montanum**
   Cells in upper part of leaf less regular, smooth at back; plants frequently characterized by numerous flagelliform branchlets ....**D. flagellare**

Dicranum spurium Hedw.

Shaded sandy soil and rocks, never on limestone. June. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: New Haven (1881), *J. A. Allen*. NEW LONDON: Ledyard, *Setchell*.*

Newfoundland to Wisconsin, south to Florida; Europe; Asia.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 228[b].

Dicranum **undulatum** Ehrh.

Moist soil and earth-covered rocks in hilly woods. Summer. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Miss Lorenz*. HARTFORD: West Hartford, *Miss Lorenz*. NEW HAVEN: East Haven (1855), *Eaton;* Meriden, *Nichols;* Woodbridge, *J. A. Allen*. MIDDLESEX: Killingworth, *Nichols*.

Canada and the northern United States; Europe; Asia.

REF. Eaton, 15, 61.

* Reported by Barron from "near the Sound" (Eaton, 15, 61).

Dicranum Bergeri Bland. *D. Schraderi* Web. f. & Mohr.

Peat bogs and wet woods. Summer. LITCHFIELD: New Milford, *Evans*. HARTFORD: West Hartford, *Miss Lorenz*. TOLLAND: Stafford, *Weatherby;* Vernon, *Miss Lorenz*. NEW HAVEN: New Haven, *J. A. Allen;* Wallingford (1878), *Barron*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Waterford, *C. B. Graves*.

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, 15, 61 (misprinted *D. Schreberi*). Miss Lorenz, 52 (incorrectly determined as *D. Muhlenbeckii*).

Dicranum scoparium (L.) Hedw.

On all sorts of substrata in moist or dry woods. Aug.-Sept. LITCHFIELD: Cornwall, *Greene;* Salisbury, *Gilman*. HARTFORD: Plainville, *Chamberlain;* West Hartford, *Miss Lorenz*. TOLLAND: Ellington and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Fairfield and Trumbull, *Eames*. NEW HAVEN: Beacon Falls, *Nichols;* East Haven, *Evans;* Hamden, *Eaton;* Meriden, *Miss Lorenz;* New Haven (1855), *Eaton;* Orange, *Evans;* Oxford, *Harger*. MIDDLESEX: Killingworth, *Nichols;* Middlefield, *Evans*. NEW LONDON: North Stonington and Waterford, *C. B. Graves*.

Throughout Canada and the United States; Europe; Asia.

REF. Eaton, 15, 61.

Dicranum fulvum Hook. *D. interruptum Brid.*

Trees and decayed logs in pine or hemlock woods in mountainous or hilly regions. Summer. NEW HAVEN: East Haven, *Hatcher;* Woodbridge (1879), *O. D. Allen*.

Newfoundland to Manitoba, south to West Virginia; Europe; Asia.

Dicranum flagellare Hedw.

On stumps and logs, and at the base of trees, in moist woods. Summer. LITCHFIELD: Norfolk, *Miss Lorenz;* Salisbury, *Gilman*. HARTFORD: West Hartford, *Miss Lorenz*. TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. WINDHAM: Can-

terbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Nichols.* NEW HAVEN: Hamden, *Nichols;* New Haven (1856), *Eaton;* Orange, *Pease;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: New London and Waterford, *C. B. Graves.*

Nova Scotia to North Carolina, and westward to British Columbia; Mexico; Europe; Asia.

REF. Eaton, **15**, 61.

Dicranum fulvum Hook. *D. interruptum* Brid.

Non-calcareous rocks in moist hilly woods. Aug.-Oct. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Burlington, *Nichols;* Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Branford, *Chatterton;* Hamden, *Pease;* New Haven (1856), *Eaton;* Orange, *Evans;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: East Lyme, New London, and Waterford, *C. B. Graves.*

Nova Scotia to Wisconsin, south to North Carolina and Missouri; Europe.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 104.

REF. Eaton, **15**, 61.

Dicranum longifolium Ehrh.

On rocks and tree trunks in mountainous or hilly regions; not on pure limestone. Late summer. NEW HAVEN: Meriden (1856), *Eaton;* Oxford, *Harger.*

Nova Scotia to North Carolina, west to British Columbia and Colorado; Greenland; Europe; Asia.

REF. Eaton, **15**, 61.*

FAMILY LEUCOBRYACEÆ

Leucobryum Hampe

Leucobryum glaucum (L.) Schimp. *L. vulgare* Hampe.

On moist soil or rocks in the woods. Fruit occasional,

* Two other species of **Dicranum**, **D. fuscescens** Turn. and **D. viride** (Sull. & Lesq.) Lindb. (as *Campylopus viridis* Sull. & Lesq.), are reported by Eaton (**15**, 61) on the authority of Barron, but no Connecticut specimens examined by the writers have been referable to either of these species.

autumn. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Mrs. Phelps.* HARTFORD: West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Trumbull, *Eames.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven, Hamden (1866), and New Haven, *Eaton;* North Haven, *Harger;* Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Nichols.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: East Lyme and North Stonington, *C. B. Graves.*

Newfoundland to the Rocky Mountains, south to Florida and Louisiana; Europe; Asia; Africa.

REF. Eaton, 15, 61.

FAMILY FISSIDENTACEÆ

Fissidens Hedw.

1. Fruit borne on the stem or on a leading branch 2
   Fruit borne on a short branch 5

2. Leaves without a border 3
   Leaves bordered by a narrow band of pale, elongated cells 4

3. Leaves obtuse, margin entire .... **F. obtusifolius**
   Leaves apiculate, margin crenulate .... **F. osmundoides**

4. Border thick, usually confluent at apex of leaf with the midrib .... **F. bryoides**
   Border narrow, almost wanting at apex of leaf; midrib percurrent .... **F. incurvus**

5. Leaves without a border 6
   Leaves bordered by several rows of paler, often thick-walled cells 7

6. Midrib percurrent .... **F. taxifolius**
   Midrib vanishing below the apex .... **F. subbasilaris**

7. Leaf cells obscure (0.007-0.009 × 0.01-0.012 mm.) ...... **F. cristatus**
   Leaf cells distinct (0.01-0.014 × 0.014-0.018 mm.) ...... **F. adiantoides**

· **Fissidens bryoides** (L.) Hedw.

On shaded earth in greenhouses, etc. Autumn. NEW HAVEN: New Haven (1876), *Veitch.*

Throughout temperate North America, and north to Yukon Territory; Europe; Asia; Africa; New Zealand.

REF. Eaton, 15, 62.*

Fissidens incurvus Schwaegr. Including *F. minutulus* Sull.

On wet shaded stones, usually in brooks. Autumn. LITCHFIELD: Salisbury, *Mrs. Phelps.* TOLLAND: Bolton and Stafford, *Nichols.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Bethany, *Evans*; Cheshire, *Harger;* East Haven (1874), *Kleeberger;* Hamden, *J. A. Allen;* Orange, *Nichols;* Oxford, *Harger.* MIDDLESEX: Middlefield, *Evans.*

Canada and the northern United States;. Cuba; Europe; Asia; Africa; New Zealand; Tasmania.

REF. Eaton, 15, 62.

Fissidens obtusifolius Wils.

Wet rocks and stones. Aug.-Sept. LITCHFIELD: Salisbury (1907), *Nichols.*

New England to Minnesota and Colorado, south to Alabama and Texas.

Fissidens adiantoides (L.) Hedw.

On shaded rocks and earth in wet places. Oct.-Dec. LITCHFIELD: New Milford and Salisbury, *Nichols.* HARTFORD: Hartford, *Miss Lorenz.* TOLLAND: Bolton, *Nichols.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Cheshire, *J. A. Allen;* East Haven (1856), *Eaton;* Madison, *Adams;* Milford, *Harger;* Orange, *Evans;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols;* Middlefield, *Evans.* NEW LONDON: Groton, *C. B. Graves.*

Newfoundland to Alaska, south to Florida and Washington; Europe; Asia; Africa; New Zealand; Tasmania.

REF. Eaton, 15, 62.

Fissidens cristatus Wils. *F. decipiens* DeNot.

On moist, preferably calcareous, rocks in hilly regions.

* "In a greenhouse, *R. Veitch;* also on the sides of a well on Church Street, New Haven, *W. T. Browne.*" Both of these stations have since probably been destroyed.

Oct.-Dec. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Hartford, *Miss Lorenz.* FAIRFIELD: Danbury (1884), *Eaton;* Sherman, *Evans.* NEW HAVEN: Orange, *Evans.*

Nova Scotia to the Rocky Mountains, and south to the Gulf States; Europe; Asia.

Fissidens taxifolius (L.) Hedw.

Moist earth and clay banks in the woods. Fruit rare, winter. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Ellington, *Nichols.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: East Haven (1874), *Kleeberger;* Hamden, *Eaton;* Madison, *Nichols;* New Haven, *Eaton;* North Haven, *Nichols;* Woodbridge, *Eaton.*

Throughout the eastern United States; Europe; Asia; Africa.

REF. Eaton, 15, 62 (incorrectly reported as *F. osmundoides*).

Fissidens osmundoides (Sw.) Hedw.

Swampy woods and borders of streams. Summer. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Stafford, *Nichols.* NEW HAVEN: Branford, *J. A. Allen;* Orange, *Evans;* Woodbridge (1866), *Eaton.*

Arctic America, Canada, and the northern United States; Europe; Asia.

Fissidens subbasilaris Hedw.

On earth and at the base of trees in the woods. Autumn. NEW HAVEN: Hamden (1878), *Eaton.*

Ontario and the eastern United States.

Octodiceras Brid.

Octodiceras Julianum (Savi) Brid. *Conomitrium Julianum* Mont.

Attached to stones and wood in springs and brooks. Spring. FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Hamden (1876), *J. A. Allen;* Meriden, *Eaton*; New Haven, *Nichols;* Woodbridge, *Eaton.*

Ontario to Montana, south to Mexico; Cuba; South America; Europe; Africa.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 16[b] (as *Conomitrium Julianum*).

REF. Mrs. E. G. Britton, **9**, 83. Eaton, **15**, 62; **16**, 244.

FAMILY POTTIACEÆ

Astomum Hampe

Astomum Sullivantii Schimp. *Systegium Sullivantii* Schimp.

Moist grassy places. Spring. NEW HAVEN: East Haven, *J. A. Allen;* Oxford, *Harger;* Woodbridge (1878), *Eaton.*

Probably throughout temperate North America.

REF. Eaton, **15**, 72.

Weisia Hedw.

Weisia viridula (L.) Hedw.

Roadsides, banks, and fields, on bare earth. Spring. LITCHFIELD: New Milford, *Nichols.* HARTFORD: Canton, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols;* Trumbull, *Eames.* NEW HAVEN: East Haven, Hamden, and Meriden, *Nichols;* New Haven (1854) and North Haven, *Eaton;* Orange, *J. A. Allen;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Waterford, *C. B. Graves.*

Throughout Canada and the United States; Europe; Asia; Africa; New Zealand; Tasmania.

REF. Eaton, **15**, 62.

Hymenostylium Brid.

Hymenostylium curvirostre (Ehrh.) Lindb. *Gymnostomum curvirostre* Hedw.

Moist rocks, usually calcareous, in mountainous or hilly regions. Summer. LITCHFIELD: Salisbury, *Evans.* HARTFORD: Windsor, *Miss Lorenz.* TOLLAND: Bolton, *Nichols.* NEW HAVEN: Hamden, *Hall.* MIDDLESEX: Killingworth, (1875) *Hall.*

Labrador to Alaska, south to California and South Carolina; Europe; Asia; Africa.

REF. Eaton, **15**, 61.

Trichostomum Hedw.

Trichostomum cylindricum (Bruch) C. Müll. *Didymodon cylindricus* Br. & Sch.

Wet non-calcareous stones in or beside brooks in mountainous or hilly regions. Fruit very rare, autumn. NEW HAVEN: Hamden (1879), *J. A. Allen;* Orange, *O. D. Allen.*

Greenland to North Carolina, west to Manitoba; South America; Europe; Asia.

Tortella (C. Müll.) Limpr.

Monoicous; plants less than 1 cm. high, loosely cæspitose; leaves linear, abruptly mucronate............... **T. cæspitosa**

Dioicous; plants 2-6 cm. high, in pulvinate tufts; leaves lanceolate, long-acuminate or cuspidate......... **T. tortuosa**

Tortella tortuosa (L.) Limpr. *Barbula tortuosa* Web. f. & Mohr.

Rocks, usually calcareous, in mountainous or hilly regions. Fruit rare, June. HARTFORD: West Hartford, *Miss Lorenz.* NEW HAVEN: Cheshire, *Harger;* Meriden, *Price;* Orange (1856), *Eaton;* New Haven, *O. D. Allen.*

Greenland, Canada, and the northern United States; Europe; Asia; Africa.

REF. Eaton, 15, 62.

Tortella cæspitosa (Schwaegr.) Limpr. *Barbula cæspitosa* Schwaegr.

Earth and roots of trees in the woods. June. LITCHFIELD: Salisbury, *Gilman.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: East Haven, *Evans;* New Haven (1856), *Eaton;* Orange, *Nichols;* Oxford, *Harger;* Woodbridge, *J. A. Allen.* NEW LONDON: North Stonington and Waterford, *C. B. Graves.*

Ontario and New England to the Gulf States, west to British Columbia; Mexico; South America; Europe; Asia; Africa.

REF. Eaton, 15, 62. Mrs. Lowe, 57.

Didymodon Hedw.

Didymodon rubellus (Hoffm.) Br. & Sch.

Wet, usually calcareous rocks, in mountainous or hilly regions. Summer. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Bolton, *Nichols.* NEW HAVEN: Woodbridge (1879), *J. A. Allen.*

Alaska, Canada, and the northern United States; Europe; Asia; Africa; Tasmania.

Barbula Hedw.

Leaves gradually acuminate, midrib percurrent......**B. fallax**
Leaves obtuse and mucronate, midrib excurrent..**B. unguiculata**

Barbula fallax Hedw.

Moist earth, walls, and rocks, in limestone districts. Nov.-Jan. LITCHFIELD: Salisbury (1905), *Nichols.*

Canada and the northern United States, north to the arctic regions; Europe; Asia; Africa.

Barbula unguiculata (Huds.) Hedw.

On all sorts of earth formations. Winter. LITCHFIELD: New Milford, *Nichols.* NEW HAVEN: East Haven and New Haven (1855), *Eaton;* Orange and Oxford, *Harger;* Wallingford, *Evans;* Woodbridge, *J. A. Allen.*

Probably throughout the northern United States and Canada; Europe; Asia; Africa.

REF. Eaton, 15, 62.

Acaulon C. Müll.

Acaulon muticum (Schreb.) C. Müll. *Sphærangium muticum* Schimp.

Clay or earth in fields. Spring. NEW HAVEN: Hamden (1878), *J. A. Allen;* New Haven, *Eaton;* Orange, *J. A. Allen.*

Probably throughout temperate North America; Europe; Africa.

REF. Eaton, 15, 61.

Phascum L.

Phascum cuspidatum Schreb.

On earth in fields and grassy places. Spring. NEW

HAVEN: East Haven and New Haven, *Eaton;* Woodbridge (1878), *J. A. Allen.*

Ontario to South Carolina, westward to the Pacific States; South America; Europe; Asia; Africa.

REF. Eaton, **15**, 61.

Pottia Ehrh.

Pottia truncatula (L.) Lindb. *P. truncata* Fürn.

In moist places,— meadows, banks of streams, etc. Autumn to spring. NEW HAVEN: Woodbridge (1878), *J. A. Allen.*

Quebec and New England to Pennsylvania; Nevada; Europe; Asia; Africa.

Tortula Hedw.

1. Growing on trunks of trees; midrib bearing gemmæ in upper half; not yet found fruiting in this country...... **T. papillosa**
   Growing on rocks; midrib not gemmiparous; frequently fruiting 2
2. Dioicous; tufts large, 2-5 cm. high; midrib excurrent into a long smooth hair-point........................**T. montana**
   Monoicous; tufts small, 5-15 mm. high; midrib excurrent into a long toothed hair-point....................**T. muralis**

Tortula muralis (L.) Hedw. *Barbula muralis* Timm.

Walls and sunny rocks. Spring. NEW LONDON: New London (1895), *C. B. Graves.*

Throughout North America; a cosmopolitan.

Tortula papillosa Wils. *Barbula papillosa* C. Müll.

Trunks of trees, rarely rocks in the open. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: East Haven and Hamden, *Nichols;* Milford, *Harger;* New Haven (1855), *Eaton;* Orange, *J. A. Allen.*

Throughout the northern Atlantic States; South America; Europe; Australia; New Zealand; Tasmania.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 235.

REF. Eaton, **15**, 62.

Tortula montana (Nees) Lindb.

Sunny rocks, usually calcareous, in mountainous or hilly regions. New Haven: East Haven (1880) and Orange, *J. A. Allen.*

Northern North America; Europe; Asia; Africa.

Encalypta Schreb.

Gemmæ wanting; monoicous; capsule smooth, peristome single .... **E. ciliata**
Gemmæ brown, slender, borne in clusters in the axils of the leaves; dioicous; capsule spirally striate, peristome double .... **E. contorta**

Encalypta ciliata (Hedw.) Hoffm.

Shaded earth or rocks in mountainous or hilly regions. Summer. New Haven: Branford (1881), *J. A. Allen.*

Arctic America, Canada and the northern United States; Europe; Asia; Africa; Australia; Hawaiian Islands.

Encalypta contorta (Wulf.) Lindb. *E. streptocarpa* Hedw.

Earth and rocks, often calcareous, in mountainous or hilly regions. Not yet found fruiting in America. Litchfield: New Milford, *Nichols;* Salisbury, *Gilman.* Hartford: West Hartford, *Miss Lorenz.* Tolland: Bolton, *Miss Lorenz.* New Haven: Branford, *J. A. Allen;* Orange (1855), *Eaton;* Woodbridge, *J. A. Allen.*

Ontario to Virginia, and westward to the Rocky Mountains; Europe; Asia.

Ref. Eaton, 15, 63.

FAMILY GRIMMIACEÆ

Glyphomitrium Brid.

Glyphomitrium incurvum (Schwaegr.) Broth. ***Ptychomitrium incurvum*** Sull.

Exposed non-calcareous rocks. Spring. Hartford: Granby, *Nichols.* Windham: Canterbury, *Mrs. Hadley.* New Haven: Cheshire, *Nichols;* Hamden and New Haven (1866), *Eaton;* Oxford, *Harger;* Woodbridge, *Evans.*

Ontario and New England to Georgia, westward to Kansas and Texas.

REF. Eaton, 15, 62.

Grimmia Ehrh.

1. Capsule shorter than stalk, emergent or exserted....**G. Olneyi**
   Capsule longer than stalk, immersed...................... 2
2. Walls of lower leaf cells sinuate....................**G. pilifera**
   Walls of lower leaf cells not sinuate..................... 3
3. Plants in small dense cushions, soft, lurid green; leaf cells rounded-quadrate, 0.009-0.01 mm. above..........**G. conferta**
   Plants in laxer cushions, more robust, coarse, brownish; leaf cells rounded, 0.006-0.007 mm. above........**G. apocarpa**

Grimmia apocarpa (L.) Hedw.

On rocks and stones of various kinds. Late spring. LITCHFIELD: Salisbury, *Gilman;* Torrington, *Mrs. Lowe.* HARTFORD: Bristol and Canton, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Cheshire, *Nichols;* Hamden, *J. A. Allen;* New Haven (1855) and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *J. A. Allen.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: New London, *C. B. Graves.*

Alaska, Canada, and the northern United States; found in most quarters of the globe.

REF. Eaton, 15, 62.

Grimmia conferta Funck.

Steep sunny rocks. Spring. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Ellington, *Nichols.* FAIRFIELD: Sherman, *Nichols.* NEW HAVEN: Hamden (1877), *O. D. Allen;* Woodbridge, *Eaton.*

Nova Scotia to the Middle Atlantic States, and westward to the Pacific; Europe; Asia; Africa.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 168.

REF. Eaton, 15, 62.

Grimmia pilifera Beauv. *G. pennsylvanica* Schwaegr.

Moist rocks in hilly woods. May-June. LITCHFIELD: New Milford and Salisbury, *Nichols.* HARTFORD: Simsbury,

Miss Lorenz. TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Stratford, *Eames.* NEW HAVEN: East Haven, *Evans;* Hamden, *J. A. Allen;* New Haven (1854), *Eaton;* Oxford and Woodbridge, *Harger.*

Nova Scotia to Minnesota, south to Georgia; Mexico; Japan.

REF. Eaton, **15**, 62.

Grimmia Olneyi Sull.

Sloping rocks and bowlders, never on limestone. Spring. NEW HAVEN: Branford and Madison, *Eaton;* Meriden, *Nichols;* New Haven (1855), *Eaton;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Ontario and New England to Georgia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 169.

REF. Eaton, **15**, 62. Sullivant, **70**, 67.

Racomitrium Brid.

Racomitrium aciculare (L.) Brid.

Shaded non-calcareous rocks along mountain or hill streams. Fruit rare, spring. LITCHFIELD: Salisbury, *Gilman.* NEW HAVEN: Hamden (1878), *Eaton;* Oxford, *Harger.* NEW LONDON: Montville, *C. B. Graves.*

Alaska, Canada, and southward to California and Alabama; Europe; Africa.

REF. Eaton, **15**, 62.

FAMILY ORTHOTRICHACEÆ

Anœctangium Hedw.

Anœctangium Mougeotii (Br. & Sch.) Lindb. *Amphoridium Mougeotii* Schimp.

Crevices of damp, shaded rocks in mountainous or hilly regions. Fruit very rare, July-Aug. NEW HAVEN: Branford and Hamden, *Eaton;* Meriden, *Price;* Woodbridge (1878), *O. D. Allen.*

Newfoundland to Alabama, westward to Alaska and Oregon; Europe; Asia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 174.

Drummondia Hook.

Drummondia clavellata Hook.

Trunks of trees in the woods. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Bloomfield, *Miss Lorenz;* Canton, *Nichols;* Hartford, *Miss Lorenz;* Southington, *Chamberlain.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Bethany and Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1855), *Eaton;* North Branford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: North Stonington and Waterford, *C. B. Graves.*

Ontario and New England, south to Alabama and Missouri; Asia.

REF. Eaton, **15**, 62.

Orthotrichum Hedw.

1. Capsule with superficial stomata; plants growing on trees .... **O. sordidum**
   Capsule with immersed stomata 2
2. Peristome single, capsule plicate when dry; plants growing on rocks 3
   Peristome double; plants growing on trees 4
3. Capsule long-exserted .... **O. anomalum**
   Capsule immersed or emergent .... **O. Lescurii**
4. Capsule smooth when dry .... **O. pusillum**
   Capsule plicate when dry 5
5. Calyptra hairy 6
   Calyptra smooth .... **O. pumilum**
6. Capsule strongly plicate, reddish brown, contracted under the mouth when dry; leaves acute .... **O. Braunii**
   Capsule not strongly plicate, pale yellowish, very slightly or not at all contracted below the mouth when dry; leaves obtuse .... **O. ohioense**

Orthotrichum sordidum Sull. & Lesq.

On trees in wet woods. Spring. HARTFORD: Hartford, *Mrs. Lowe.* TOLLAND: Ellington, *Pease.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: New Haven (1876), *Pease.*

New Brunswick to Pennsylvania and Lake Superior.

REF. Eaton, **15**, 63.

Orthotrichum anomalum Hedw.

Rocks in the open. Spring. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: Branford (1881), *J. A. Allen*.

Throughout Canada and the northern United States; Alaska; Europe; Asia; Africa.

Orthotrichum Lescurii Aust. *O. cupulatum* Hoffm. var. *minus* Sull.

Dry shaded granite or trap rocks. Spring. NEW HAVEN: Hamden (1876), *Pease;* Woodbridge, *Eaton*.

Ontario and New England, south to Pennsylvania and Missouri, and in the Rocky Mountain region.

REF. Austin, **3**, 341. Eaton, **15**, 63.

Orthotrichum pusillum Mitt. *O. psilocarpum* James.

On trunks of trees. Spring. NEW HAVEN: New Haven (1877), *J. A. Allen;* Oxford, *Harger*.

New England and New York to Georgia, west to Missouri.

REF. Eaton, **15**, 63. Rau & Hervey, **64**, 21.

Orthotrichum Braunii Br. & Sch. *O. strangulatum* Sull. not Beauv.

Trunks of trees. Spring. TOLLAND: Ellington, *Pease*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: New Haven (1886), *Eaton*.

Prince Edward Island to Georgia, westward to Iowa; Europe; Asia; Africa.

REF. Eaton, **15**, 63.

Orthotrichum ohioense Sull. & Lesq.

Trunks of trees. Spring. HARTFORD: Southington, *Chamberlain*. TOLLAND: Ellington, *Pease*. FAIRFIELD: Trumbull, *Eames*. NEW HAVEN: Hamden (1875), *Young;* Madison, *Nichols;* New Haven, *Pease*. MIDDLESEX: Chester and Killingworth, *Nichols*. NEW LONDON: Groton and North Stonington, *C. B. Graves*.

Prince Edward Island to Georgia, west to Michigan.

REF. Eaton, **15**, 63.

Orthotrichum pumilum Sw.

On trees. Spring. LITCHFIELD: Salisbury (1907), *Nichols*.

New England and Ontario to Idaho, south to Florida and Texas; Europe; Asia; Africa.

Ulota Mohr

1. Leaves rigid when dry; plants growing on rocks. **U. Hutchinsiæ**
   Leaves crispate when dry; plants growing on trees....... 2
2. Capsule smooth, slightly plicate only below the narrowed mouth .... **U. Ludwigii**
   Capsule longitudinally plicate throughout, mouth wide.... 3
3. Capsule constricted below the mouth, gradually narrowed toward the neck when dry and empty........ **U. ulophylla**
   Capsule slightly or not at all contracted below the mouth, abruptly narrowed toward the neck............ **U. crispula**

Ulota Hutchinsiæ (Sm.) Hammar. *U. americana* (Beauv.) Limpr.. Not Mitt.

Non-calcareous rocks in mountainous or hilly districts. Spring. LITCHFIELD: Kent, *Eames;* New Milford, *Nichols;* Salisbury, *Gilman*. HARTFORD: Hartford, *Mrs. Lowe*. TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Sherman, *Nichols*. NEW HAVEN: Madison and Meriden, *Nichols;* New Haven (1854), *Eaton;* Oxford, *Harger*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Groton and Waterford, *C. B. Graves*.

New Brunswick to Georgia, westward to the Rocky Mountains; Europe; Asia.

REF. Eaton, **15**, 63.

Ulota Ludwigii Brid.

Trunks of trees in mountainous or hilly woods. Summer. LITCHFIELD: Salisbury, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Branford, *Eaton;* East Haven, *J. A. Allen;* Hamden and Woodbridge (1866), *Eaton*. MIDDLESEX: Chester and Killingworth, *Nichols*.

Newfoundland to Ontario and North Carolina; Europe.

REF. Eaton, **15**, 63.

Ulota ulophylla (Ehrh.) Broth. *U. crispa* (Hedw.) Brid.

Trees in the woods. Summer. LITCHFIELD: Salisbury, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: North Haven, *Nichols;* Oxford, *Harger*. MIDDLESEX: Chester and Killingworth, *Nichols*. NEW LONDON: East Lyme and North Stonington (1894), *C. B. Graves*.

Newfoundland to Wisconsin, south to Georgia; Alaska; Europe; Asia; Canary Islands.

REF. Eaton, 15, 63.

Ulota crispula Bruch.

Trees in the woods. Summer. HARTFORD: Hartford, *Mrs. Lowe*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Woodbridge (1866), *Eaton*. MIDDLESEX: Saybrook, *Eaton*.

Same range as the preceding species.

REF. Eaton, 15, 63.

FAMILY FUNARIACEÆ

Ephemerum Hampe

1. Leaves without a midrib 2
   Midrib present, percurrent or nearly so ...... **E. crassinervium**
2. Leaves obscurely serrulate; stomata present in upper half of capsule .... **E. megalosporum**
   Leaves distinctly serrulate; stomata restricted to base of capsule .... **E. serratum**

Ephemerum megalosporum (Aust.) Salm. *Micromitrium megalosporum* Aust.

Wet or periodically inundated earth. Autumn. NEW HAVEN: Orange (1891), *Evans*.

Connecticut to Georgia.

Ephemerum serratum (Schreb.) Hampe.

Wet, clayey earth. Autumn. NEW HAVEN: East Haven, *Evans;* New Haven, *Nichols;* Orange, *Eaton;* Oxford, *Harger*. NEW LONDON: Norwich (1888), *Setchell*.

Probably throughout temperate North America; Europe.

Ephemerum crassinervium (Schwaegr.) C. Müll.

Damp earth in fields. Autumn. NEW HAVEN: East Haven (1891), *Evans*.

New England to Minnesota, south to Florida.

Aphanorrhegma Sull.

Aphanorrhegma serratum (Hook. & Wils.) Sull.

Moist, sandy soil in fields. Autumn. FAIRFIELD: Danbury, *Nichols*. MIDDLESEX: Cromwell (1900), *Evans*.

Temperate North America.

Physcomitrium (Brid.) Br. & Sch.

Physcomitrium turbinatum (Michx.) C. Müll. *P. pyriforme* of some authors.

On earth in gardens and fields. May-June. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Hartford (1855), *Eaton*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Eames*. NEW HAVEN: New Haven, *Eaton;* North Branford, *Evans;* North Haven, *Nichols;* Oxford, *Harger*. NEW LONDON: New London, *C. B. Graves*.

Quebec to Florida, and west to the Rocky Mountains.

REF. Eaton, **15**, 63. Mrs. Hadley, **40**.

Funaria Schreb.

Funaria hygrometrica (L.) Schreb.

Earth in fields, along roadsides, in burnt-over woods and waste places. May-June. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Hartford, *Miss Lorenz;* Windsor, *W. E. Britton*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Eames*. NEW HAVEN: Beacon Falls, *Nichols;* New Haven (1856), *Eaton;* Orange, *Evans*.

Throughout North America; a cosmopolitan.

REF. Eaton, **15**, 63.

FAMILY BRYACEÆ

Leptobryum (Br. & Sch.) Wils.

Leptobryum pyriforme (L.) Wils.

On moist shaded soil or old walls and on rotten wood. June-July. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Hartford, *Miss Lorenz*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe*. NEW HAVEN: Branford, *O. D. Allen;* New Haven (1855), *Eaton;* Orange, *Evans*.

Throughout North America; South America; Europe; Asia; Tasmania; New Zealand.

REF. Eaton, 15, 63.

Pohlia Hedw.

1. Plants producing gemmæ in axils of leaves, rarely fruiting **P. proligera**
   Plants not gemmiparous, richly fruiting.................. 2
2. Basal membrane of inner peristome one-third to one-half height of segments ....**P. nutans**
   Basal membrane of inner peristome one-fourth height of segments ....**P. cruda**

Pohlia cruda (L.) Lindb.

Shaded earth and fissures of rocks in mountainous or hilly regions. Early summer. NEW HAVEN: Derby (1881), *J. A. Allen.*

Greenland to Pennsylvania, and westward to the Pacific; found in most quarters of the globe.

Pohlia nutans (Schreb.) Lindb. *Webera nutans* Hedw.

Soil and decaying wood in fields or woods. Early summer. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Southington, *Chamberlain.* TOLLAND: Stafford and Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls and East Haven, *Nichols;* New Haven (1874), *Kleeberger;* North Haven, *Evans;* Oxford, *Harger;* Woodbridge, *J. A. Allen.* MIDDLESEX: Durham, *Evans.* NEW LONDON: Ledyard, *C. B. Graves.*

Throughout most of North America; a cosmopolitan.

REF. Eaton, 15, 63. Mrs. Hadley, 43.

Pohlia proligera Lindb.

On earth. Fruit rare, summer. NEW HAVEN: Beacon Falls and Hamden, *Nichols;* New Haven (1905), *Evans.*

Widely distributed throughout Canada and the United States; Alaska; Europe.

Mniobryum (Schimp.) Limpr.

Mniobryum albicans (Wahl.) Limpr. *Webera albicans* Schimp.

In swamps and on sandy banks of streams. Early summer. HARTFORD: Bloomfield and Farmington, *Mrs. Lowe.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Hamden (1855), *Eaton.*

Arctic America, Canada, and the northern United States; south in the east to Florida; found in most quarters of the globe.

REF. Eaton, 15, 63.

Bryum (Dill.) L.

1. Plants monoicous (synoicous); leaves with a broad border, midrib excurrent into a short point................**B. bimum**
   Plants dioicous 2
2. Midrib vanishing below the apex, leaves not bordered, or very indistinctly so ....**B. argenteum**
   Midrib excurrent (or frequently vanishing below the apex in *B. capillare*) 3
3. Leaves short-cuspidate, distinctly bordered....**B. ventricosum**
   Leaves long-cuspidate 4
4. Leaves bordered, twisted when dry...............**B. capillare**
   Leaves not bordered or only faintly so, scarcely twisted when dry ....**B. cæspiticium**

Bryum ventricosum Dicks. *B. pseudotriquetrum* (Hedw.) Schwaegr.

Wet, swampy places. Early summer. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: New Haven (1859), *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Arctic America, Canada, and the northern United States; found all over the world.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 246 (as *B. pseudotriquetrum*).

REF. Eaton, 15, 63.

Bryum bimum Schreb.

On wet rocks and on the ground in swampy woods. Early summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Farmington, *Mrs. Lowe;* Plainville, *Chamberlain.* TOLLAND: Bolton, *Nichols;* Ellington, *Pease.* WINDHAM: Canterbury,

Mrs. Hadley. NEW HAVEN: New Haven (1856), *Eaton.* NEW LONDON: New London, *C. B. Graves.*

Arctic America, Canada, and southward to Florida and Arizona; a cosmopolitan.

REF. Eaton, **15**, 63.

Bryum cæspiticium L.

On the ground in old pastures and fields. Early summer. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Trumbull, *Eames.* NEW HAVEN: New Haven (1855), *Eaton;* Orange, *Nichols.* NEW LONDON: New London, *C. B. Graves.*

Throughout North America; a cosmopolitan.

REF. Eaton, **15**, 63. Mrs. Lowe, **54**.

Bryum argenteum L.

On earth or earth-covered rocks. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols.* NEW HAVEN: Hamden, *Evans;* Meriden, *Miss Lorenz;* New Haven (1854), *Eaton.* MIDDLESEX: Old Lyme, *Nichols.*

Throughout North America; a cosmopolitan.

REF. Eaton, **15**, 63.

Bryum capillare L.

Rich, loamy soil, and roots of trees in the woods. Early summer. NEW HAVEN: Cheshire, *J. A. Allen;* East Haven, *Nichols;* Hamden (1879) *J. A. Allen.*

Throughout temperate North America, and north to the arctic regions; Mexico; Europe; Asia; Africa.

Rhodobryum (Schimp.) Hampe

Rhodobryum roseum (Weis) Limpr. *Bryum roseum* Schreb.

Rotten logs and humus in moist woods. Fruit occasional, autumn. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Hartford, *Mrs. Lowe;* Southington, *Chamberlain.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Eaton.*

NEW HAVEN: Hamden, *Evans;* Meriden, *Eaton;* Milford, *Harger;* New Haven (1855) and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Nichols.* MIDDLESEX: Killingworth, *Nichols.*

New Brunswick to Nebraska, south to Georgia; California; Europe; Asia; Africa.

REF. Eaton, 15, 63.

FAMILY MNIACEÆ

Mnium (Dill.) L.

1. Leaf cells not arranged in oblique rows; border of leaves several cells thick; marginal teeth in pairs 2
   Leaf cells tending to be arranged in diverging rows, gradually increasing in size from the border toward the midrib 5
2. Lid strongly convex, mammiform or apiculate; midrib toothed at back .... **M. hornum**
   Lid rostrate 3
3. Midrib smooth at back; monoicous (synoicous) 4
   Midrib toothed at back; dioicous .... **M. orthorrhynchum**
4. Perichætial leaves forming a rosette, not crispate when dry; capsules borne in clusters .... **M. spinulosum**
   Perichætial leaves not forming a rosette, crispate when dry; capsules borne singly .... **M. marginatum**
5. Leaves serrate, teeth single, border one cell thick 6
   Leaves entire 11
6. Monoicous (synoicous) 7
   Dioicous 9
7. Lid rostrate; stomata scattered over the entire capsule .. **M. rostratum**
   Lid strongly convex, apiculate; stomata present only on neck of capsule 8
8. Capsules borne singly; leaves serrate to middle .. **M. cuspidatum**
   Capsules borne in clusters; leaves serrate to base .. **M. medium**
9. Margin of leaves obscurely toothed .... **M. rugicum**
   Marginal teeth of 2-4 cells 10
10. Marginal teeth robust .... **M. affine**
    Marginal teeth slender .... **M. ciliare**
11. Border narrow, scarcely thickened, of one layer of cells .. **M. cinclidioides**
    Border broad, thickened .... **M. punctatum**

Mnium hornum L.

Moist banks and wet rocks in the woods. May-June. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: East Hartford and Manchester, *Miss Lorenz*. TOLLAND: Ellington, *Pease*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Monroe, *Miss Lorenz*. NEW HAVEN: Beacon Falls, *Nichols;* East Haven (1875), *Eaton;* Hamden, *J. A. Allen;* New Haven and North Haven, *Nichols;* Orange, *Pease;* Oxford, *Harger*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Groton and Ledyard, *C. B. Graves;* Waterford, *Miss Lorenz*.

Newfoundland to Wyoming, and southward to Georgia; Europe; Asia; Africa.

REF. Mrs. E. G. Britton, **8**, 4. Eaton, **15**, 63. Mrs. Hadley, **40**.

Mnium orthorrhynchum Br. & Sch.

Rocks and soil, usually calcareous, in shaded ravines. July-Aug. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: Wallingford (1874), *Barron*.

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, **15**, 63.

Mnium marginatum (Dicks.) Beauv. ***M. serratum*** Schrad.

Shaded banks and rocks near streams and in moist woods. May-June. LITCHFIELD: Cornwall, *Brewster;* Salisbury, *Gilman*. FAIRFIELD: Darien, *Mrs. Lowe*. NEW HAVEN: Ansonia, *J. A. Allen;* Cheshire, *Evans;* Hamden, *Eaton;* New Haven (1878), *J. A. Allen;* Orange, *Evans*. MIDDLESEX: Durham, *Evans*. NEW LONDON: Waterford, *C. B. Graves*.

Canada, Alaska, and the northern United States; Europe; Asia.

Mnium spinulosum Br. & Sch.

On the ground in evergreen mountain or hill woods. May-June. LITCHFIELD: Salisbury, *Gilman*. FAIRFIELD: Darien, *Mrs. Lowe*. NEW HAVEN: Hamden (1881), *J. A. Allen*.

Nova Scotia and the northern Atlantic States, westward to Alaska and Washington; Europe; Asia.

Mnium rostratum Schrad.

Shaded rocks in wet ravines. May-June. LITCHFIELD: Salisbury, *Nichols*. FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols*. NEW HAVEN: Hamden (1880), *J. A. Allen;* Woodbridge, *O. D. Allen*. MIDDLESEX: East Haddam, *C. B. Graves*. NEW LONDON: Waterford, *C. B. Graves*.

Throughout temperate North America, and in most temperate regions of the globe.

REF. Mrs. E. G. Britton, **8**, 5.

Mnium cuspidatum (L.) Leyss. *M. sylvaticum* Lindb.

Earth, stones, or old logs in moist woods. May-June. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Hartford, *Mrs. Lowe;* Windsor, *W. E. Britton*. TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Fairfield, *Eames;* Monroe, *Miss Lorenz;* Sherman, *Nichols;* Trumbull, *Eames*. NEW HAVEN: East Haven (1875), *Eaton;* Madison, *Nichols;* New Haven, *Eaton;* North Branford and North Haven, *Evans*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Groton and Montville, *C. B. Graves;* Norwich, *Setchell;* Waterford, *C. B. Graves*.

Newfoundland to Florida and westward to the Pacific; Europe; Asia.

REF. Eaton, **15**, 63. Mrs. Hadley, **41**.

Mnium medium Br. & Sch.

On earth or rotting stumps in moist, shaded places. May-June. LITCHFIELD: Norfolk (1877), *Eaton*. NEW HAVEN: New Haven, *Eaton*.

Greenland to Pennsylvania, westward to Alaska and California; Europe; Asia.

Mnium ciliare (Grev.) Lindb. *M. affine* var. *ciliare* C. Müll.

Moist sandy soil in woods. May-June. LITCHFIELD: Salisbury, *Gilman*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Beacon Falls and East Haven, *Nichols;* Hamden (1858), *Eaton;* Woodbridge, *Chatterton*.

Nova Scotia to Louisiana, westward to British Columbia; Europe; Asia.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 247.

REF. Mrs. E. G. Britton, **8**, 5.

Mnium affine Bland.

Moist earth and rocks in woods and swamps. May-June. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: Hartford, *Mrs. Lowe;* Southington, *Chamberlain*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Ansonia, *J. A. Allen;* Beacon Falls and East Haven, *Nichols;* Hamden (1865), *Eaton;* Orange, *Evans;* Woodbridge, *J. A. Allen*. MIDDLESEX: Durham, *Evans;* Killingworth, *Nichols*.

Throughout northern North America, south to Florida and California; Europe; Asia; Africa.

REF. Eaton, **15**, 63.

Mnium rugicum Laur. *M. affine* var. *rugicum* Br. & Sch.

On the ground in shaded swamps and ravines. May-June. FAIRFIELD: Sherman, *Nichols*. NEW HAVEN: Hamden (1880), *Eaton;* Woodbridge, *Setchell*.

Greenland and Labrador to Alaska, south to Louisiana and Colorado; Europe.

Mnium punctatum (L.) Hedw.

On the ground in swamps or wet woods. Spring. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: East Hartford, *Miss Lorenz;* Hartford, *Mrs. Lowe;* Windsor, *Miss Lorenz*. WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols*. NEW HAVEN: Bethany, *O. D. Allen;* Cheshire, *Eaton;* Derby, *Eames;* Hamden (1855), *Eaton;* Orange, *Nichols;* Oxford, *Harger;* Woodbridge, *Eaton*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Groton, *C. B. Graves;* Ledyard, *Nichols;* Montville, Stonington, and Waterford, *C. B. Graves*.

Var. **elatum** Schimp.

LITCHFIELD: Norfolk, *Eaton;* Salisbury, *Nichols*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley;* Thompson, *Miller*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1875) *Eaton*.

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Mrs. E. G. Britton, **8**, 5. Eaton, **15**, 64.

Mnium cinclidioides Hüben.

Swamps, pools, and wet places in the woods. Fruit rare, June. LITCHFIELD: Litchfield, *T. F. Allen.* HARTFORD: Farmington (1859), *Eaton.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven, *J. A. Allen;* Hamden and Orange, *Eaton;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols;* Saybrook, *Eaton.* NEW LONDON: Norwich, *Harger.*

Northern North America, south in the east to Pennsylvania; Europe; Asia.

REF. Eaton, **15**, 64.

FAMILY AULACOMNIACEÆ

Aulacomnium Schwaegr.

Monoicous; leaves coarsely serrate in upper half; plants not gemmiparous .... **A. heterostichum**

Dioicous; leaves serrulate near apex; sterile plants frequently producing gemmæ at the tips of flagelliform branches .... **A. palustre**

Aulacomnium heterostichum (Hedw.) Br. & Sch.

Moist banks and roots of trees in the woods. May-June. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Burlington, *Nichols;* Farmington, *Mrs. Lowe;* Hartford, *Miss Lorenz;* Southington, *Chamberlain;* Windsor, *Rorer.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe.* NEW HAVEN: Ansonia, *J. A. Allen;* Beacon Falls, *Nichols;* East Haven, *Evans;* Hamden (1858), *Eaton;* Madison and Meriden, *Nichols;* New Haven, *J. A. Allen;* Woodbridge, *Setchell.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: East Lyme, *C. B. Graves;* Ledyard, *Nichols;* North Stonington, *C. B. Graves.*

Ontario to Wisconsin, south to Florida and Texas; Asia.

REF. Eaton, **15**, 64.

Aulacomnium palustre (L.) Schwaegr.

In bogs and swampy woods. June. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols;* Farmington, *Mrs. Lowe;* West Hartford, *Miss Lorenz.* TOLLAND: Ellington, *Pease;* Willington, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Nichols.* NEW HAVEN: East Haven, *Eaton;* Madison, *Miss Lorenz;* Meriden, *Nichols;* New Haven (1855), *Eaton;* Oxford, *Harger.* MIDDLESEX: Chester, *Nichols;* Durham, *Evans;* Killingworth, *Nichols.* NEW LONDON: North Stonington, Old Lyme, and Waterford, *C. B. Graves.*

Arctic America, southward to the mountains of South Carolina, Utah, and California; South America; Europe; Asia; Australia.

REF. Eaton, **15**, 64. Mrs. Hadley, **40**.

FAMILY MEESIACEÆ

Meesia Hedw.

Meesia triquetra (L.) Aongstr. *M. tristicha* Br. & Sch.

In wet meadows and peat bogs. June-July. HARTFORD: Berlin (1875), *Coleman.* NEW HAVEN: New Haven, *J. A. Allen.*

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, **15**, 64.

FAMILY BARTRAMIACEÆ

Plagiopus Brid.

Plagiopus Oederi (Gunn.) Limpr. *Bartramia Oederi* Sw.

Moist calcareous rocks or soil in mountainous and hilly woods. Spring. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: West Hartford, *Miss Lorenz.* FAIRFIELD: Monroe, *Harger;* Sherman, *Nichols.* NEW HAVEN: Cheshire (1856), *Eaton;* Hamden, *J. A. Allen;* Meriden, *Eaton.*

Canada and the northern United States, south in the east to North Carolina; Europe; Asia.

REF. Eaton, **15**, 64.

Bartramia Hedw.

Bartramia pomiformis (L.) Hedw.

Rocks or soil in moist woods. Spring. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Hartford, *Mrs. Lowe;* Southington, *Chamberlain;* West Hartford, *Miss Lorenz;* Windsor, *W. E. Britton.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Huntington and Sherman, *Nichols;* Trumbull, *Eames.* NEW HAVEN: Beacon Falls and East Haven, *Nichols;* Hamden, *Eaton;* Madison and Meriden, *Nichols;* New Haven (1855), *Eaton;* North Haven, *Nichols;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* North Stonington, *C. B. Graves.*

Arctic America and Canada, southward to Alabama and Colorado; South America; Europe; Asia; Africa; New Zealand.

REF. Eaton, **15**, 64.

Philonotis Brid.

Philonotis fontana (L.) Brid.

In swamps or wet places and on dripping rocks, rarely on limestone. Fruit occasional, June. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Todd.* HARTFORD: Hartford and Windsor, *Miss Lorenz.* TOLLAND: Bolton, *Nichols;* Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols;* FAIRFIELD: Easton, *Eames;* Huntington, *Nichols;* Redding, *Evans.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1856) and North Branford, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Groton and Ledyard, *C. B. Graves.*

Arctic and temperate North America, south in the east to Florida; a cosmopolitan.

REF. Eaton, **15**, 64.

FAMILY TIMMIACEÆ

Timmia Hedw.

Timmia cucullata Michx. *T. megapolitana* of American authors, in part.

On moist shaded banks, especially in limestone regions. Spring. LITCHFIELD: Cornwall, *Hall;* Salisbury, *Gilman.* HARTFORD: Windsor, *Miss Lorenz.* NEW HAVEN: Hamden, *Eaton;* Woodbridge (1878), *Brewster.*

Newfoundland to Pennsylvania and westward to the Pacific; Europe.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 183 (as *T. bavarica* var. *cucullata*).

REF. Eaton, **15**, 72.

FAMILY HEDWIGIACEÆ

Hedwigia Ehrh.

Hedwigia albicans (Web.) Lindb. *H. ciliata* Ehrh.

On rocks and bowlders of various kinds, but never on limestone. Spring. LITCHFIELD: New Milford and Salisbury, *Nichols.* HARTFORD: Hartford, *Mrs. Lowe;* Plainville, *Chamberlain.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Huntington, *Nichols;* Stratford, *Eames.* NEW HAVEN: East Haven, *Evans;* Hamden, *Eaton;* Madison and Meriden, *Nichols;* New Haven and Orange (1873), *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* Waterford, *C. B. Graves.*

Throughout North America, and in most quarters of the globe.

REF. Eaton, **15**, 62.

FAMILY FONTINALACEÆ

Fontinalis (Dill.) L.

1. Stem leaves keeled .... **F. antipyretica**
   Leaves not keeled 2
2. Leaves 2-3 mm. long, firm, very concave throughout and incurved at the margins .... **F. dalecarlica**
   Leaves 3.5-7 mm. long, slightly concave 3
3. Branches obliquely spreading; leaves flaccid, plane in the upper half .... **F. Lescurii**
   Branches widely spreading; leaves firmer, concave throughout .... **F. Novæ-Angliæ**

Fontinalis antipyretica L. var. **gigantea** Sull.

On stones and wood in flowing water. Fruit occasional, summer. LITCHFIELD: Goshen, *Underwood;* Salisbury, *Mrs. Phelps.* HARTFORD: Burlington and Granby, *Nichols;* West Hartford, *Miss Lorenz.* TOLLAND: Bolton, *Nichols;* Somers, *Pease;* Stafford, *Nichols.* NEW HAVEN: Bethany, *Eaton;* Cheshire, *Nichols;* Hamden, *J. A. Allen;* New Haven (1856), *Smith;* Orange and Oxford, *Harger.*

Canada and the northern United States; Europe; Asia; Africa.

REF. Eaton, **15**, 65.

Fontinalis dalecarlica Schimp.

On stones in rapid mountain or hill streams. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Burlington, *Nichols;* West Hartford, *Miss Lorenz.* TOLLAND: Vernon, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1866), *Eaton.* MIDDLESEX: Chester and Killingworth, *Nichols.* NEW LONDON: Ledyard, *C. B. Graves.*

Greenland and Labrador to Kansas, south to Alabama; Europe.

REF. Eaton, **15**, 65.

Fontinalis Novæ-Angliæ Sull.

Pools and running water in streams. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Burlington, *Nichols.* TOLLAND: Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Beacon Falls, *Nichols;* Bethany, *Eaton;* East Haven, *Nichols;* Hamden, *J. A. Allen;* Meriden and New Haven (1855), *Eaton;* Orange, *J. A. Allen.* NEW LONDON: Groton, *C. B. Graves.*

Newfoundland to Ontario, and south to North Carolina.

REF. Eaton, **15**, 65. Lesquereux & James, **50**, 271. Sullivant, **68**, 654 (as *F. biformis* Sull.); **69**, 54 (as *F. biformis*), 104; **70**, 105.

Fontinalis Lescurii Sull.

On stones in streams. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Bloomfield, *Miss Lorenz;* Burlington,

Nichols. TOLLAND: Stafford, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Derby, *O. D. Allen;* Hamden, *J. A. Allen;* New Haven (1855), *Eaton;* Wallingford, *Barron;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.*

Nova Scotia to Alabama, westward to the Rocky Mountains.

REF. Eaton, **15**, 65.

Dichelyma Myrin

Dichelyma capillaceum (L.) Schimp.

On bushes and sticks in ponds and water holes. Summer. TOLLAND: Stafford and Willington, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Branford and East Haven, *Eaton;* Hamden, *Nichols;* New Haven (1855) and Orange, *Eaton.* MIDDLESEX: Saybrook, *Eaton.* NEW LONDON: North Stonington and Waterford, *C. B. Graves.*

New Brunswick to Ontario and Pennsylvania; Europe.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 187.

REF. Eaton, **15**, 65.

FAMILY CRYPHÆACEÆ

Cryphæa Mohr

Cryphæa glomerata Br. & Sch.

Trunks of trees in the woods. Spring. NEW HAVEN: Hamden (1875), *Young.*

Connecticut to Ohio, south to the Gulf of Mexico.

REF. Eaton, **15**, 64. Rau, **63**, 152. Rau & Hervey, **64**, 52.

FAMILY LEUCODONTACEÆ

Leucodon Schwaegr.

Capsule exserted beyond the perichætial leaves....**L. julaceus**
Capsule exserted but surpassed by the perichætial leaves.. **L. brachypus**

Leucodon julaceus (L.) Sull.

Trunks of trees in the woods. Autumn. WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: New Haven (1855), *Eaton;* North Branford, *Harger;* Orange, *Eaton;* Oxford, *Harger.* NEW LONDON: North Stonington, *C. B. Graves.*

New England to Michigan, south to Florida and Texas.
REF. Eaton, 15, 65.

Leucodon brachypus Brid.

Trees and rocks in mountainous or hilly woods. Fruit rare, autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols;* Hartford, *Miss Lorenz.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Guilford and New Haven (1856), *Eaton.* MIDDLESEX: Killingworth, *Nichols.*

Nova Scotia to Kansas, south to the Gulf States.
REF. Eaton, 15, 65.

Forsstroemia Lindb.

Forsstroemia trichomitria (Hedw.) Lindb. *Leptodon trichomitrion* Mohr.

On trees in the woods, rarely on rocks. Autumn. HARTFORD: Hartford, *Mrs. Lowe;* West Hartford, *Miss Lorenz.* NEW HAVEN: Cheshire, *Eaton;* Hamden, *J. A. Allen;* New Haven, *Evans;* North Haven, *Eaton;* Orange, *J. A. Allen;* Waterbury (1855), *Blackman;* Woodbridge, *Evans.* MIDDLESEX: Saybrook, *Eaton.*

Ontario and New England, south to the Gulf States; Asia.
REF. Eaton, 15, 65.

FAMILY NECKERACEÆ

Neckera Hedw.

Neckera pennata (L.) Hedw.

On trees and moist rocks in mountainous or hilly woods. Autumn. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Hartford, *Miss Lorenz.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Branford, East Haven, and New Haven (1855), *Eaton;* Southbury, *Harger;* Woodbridge, *Evans.* MIDDLESEX: Chester, *Nichols;* Saybrook, *Eaton.*

Nova Scotia to Manitoba and Yukon Territory, south to North Carolina; found in most temperate regions of the world.
EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 188.
REF. Eaton, 15, 65.

Homalia (Brid.) Br. & Sch.

Homalia Jamesii Schimp.

Rocks and crevices in mountainous or hilly districts. Autumn. LITCHFIELD: Salisbury, *Miss Lorenz.* NEW HAVEN: Hamden (1881), *J. A. Allen.*

Newfoundland and Nova Scotia to Pennsylvania; Washington.

FAMILY ENTODONTACEÆ

Schwetschkeopsis Broth.

Schwetschkeopsis denticulata (Sull.) Broth. *Leskea denticulata* Sull.

At the base of trees or on rocks. Fruit rare. NEW HAVEN: Orange (1880), *O. D. Allen.*

Connecticut and New York to Florida, west to the Mississippi River; Asia.

Platygyrium Br. & Sch.

Platygyrium repens (Brid.) Br. & Sch.

On roots and trunks of trees, especially chestnut and beech, on old logs, stumps, and stones. Autumn. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Sherman, *Nichols.* NEW HAVEN: East Haven, *O. D. Allen;* Hamden, *Evans;* New Haven (1855), *Eaton;* North Haven, *Evans;* Oxford, *Harger.* MIDDLESEX: Middlefield, *Evans.* NEW LONDON: New London, *C. B. Graves.*

North America, west to the Rocky Mountains; Europe; Asia; Africa.

REF. Eaton, 15, 66.

Entodon C. Müll.

Branches usually complanate; annulus clearly differentiated; teeth 12-18-articulate .... **E. cladorrhizans**

Branches usually terete; annulus not clearly defined; teeth 7-10-articulate .... **E. seductrix**

Entodon cladorrhizans (Hedw.) C. Müll. *Cylindrothecium cladorrhizans* Schimp.

On decaying logs, on stones, and at the base of trees in moist woods. Autumn. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Southington, *Chamberlain*. TOLLAND: Ellington, *Pease*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols*. NEW HAVEN: Hamden, *J. A. Allen;* Madison, *Nichols;* Orange, *Eaton;* Oxford, *Harger;* Woodbridge (1866), *Eaton*.

New Brunswick to Minnesota, and south to the Gulf States; Europe.

REF. Eaton, **15**, 66.

Entodon seductrix (Hedw.) C. Müll. *Cylindrothecium seductrix* Sull.

On decaying wood, earth, rocks, and roots of trees in moist woods. Autumn. HARTFORD: Hartford, *Miss Lorenz*. TOLLAND: Bolton and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Eaton;* Darien, *Mrs. Lowe;* Sherman, *Nichols*. NEW HAVEN: East Haven, Hamden, and Madison, *Nichols;* New Haven and Orange (1855), *Eaton;* Oxford, *Harger;* Woodbridge, *J. A. Allen*. MIDDLESEX: Killingworth, Nichols.

New England to Minnesota, south to Florida and Texas.

EXSIC. Grout, N. Amer. Musci Pleuro. Nos. 51, 173.

REF. Eaton, **15**, 66.

Pylaisia Br. & Sch.

1. Segments of inner peristome entirely free from teeth, basal membrane distinct; spores 0.008-0.012 mm. in diameter .... **P. subdenticulata**
 Segments of inner peristome partially or wholly adherent to teeth, basal membrane obscure or lacking 2
2. Partially adherent; spores 0.016-0.024 mm. in diameter.... **P. Schimperi**
 Wholly adherent; spores 0.025-0.032 mm. in diameter..... **P. intricata**

Pylaisia Schimperi Card. *P. intricata* of some authors.

Bark of trees or decaying wood in the woods or in the open. Autumn. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Canton, *Nichols;* Hartford, *Miss Lo-*

renz; Southington, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Branford (1874), *Kleeberger:* East Haven, *Evans;* Hamden, *Eaton;* New Haven, *J. A. Allen;* Orange and Woodbridge, *Veitch.* MIDDLESEX: Chester, *Nichols.* NEW LONDON: New London, *C. B. Graves.*

New Brunswick to the Gulf States, westward to the Rocky Mountains; Europe; Asia.

REF. Eaton, **15**, 66.

Pylaisia subdenticulata Schimp.

On rocks and at the base of trees in the woods. Autumn. TOLLAND: Ellington (1876), *Pease.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: New Haven, *J. A. Allen.*

New England to Illinois, southward to Florida and New Mexico.

Pylaisia intricata (Hedw.) Br. & Sch. *P. velutina* Schimp.

On stumps and trees in mountainous or hilly woods. Autumn. LITCHFIELD: Salisbury, *Nichols.* NEW HAVEN: East Haven, *O. D. Allen;* Hamden, *Young;* Milford, *Harger;* New Haven (1855), *Eaton.*

Newfoundland to Ontario, south to North Carolina.

REF. Eaton, **15**, 66.

Homalothecium Br. & Sch.

Homalothecium subcapillatum (Hedw.) Sull.

Trunks of trees in the woods. Autumn. FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Cheshire (1855), *Blackman;* East Haven and New Haven, *Eaton;* Woodbridge, *Pease.*

New England to North Carolina.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 108.

REF. Eaton, **15**, 66.

FAMILY FABRONIACEÆ

Anacamptodon Brid.

Anacamptodon splachnoides (Fröl.) Brid.

On trunks and decaying shelves of trees, in forks, around knot holes full of water, on old stumps and logs, from sea level

to high altitudes. Local. Spring. HARTFORD: East Hartford, *Mrs. Lowe.* NEW HAVEN: Cheshire, Hamden, and New Haven, *Nichols;* Wallingford (1880), *O. D. Allen.*

New England to Alabama, west to Illinois and Texas; Europe; Asia.

REF. Mrs. Lowe, **56**.

FAMILY LESKEACEÆ

Thelia Sull.

1. Papillæ of leaves simple .... **T. hirtella**
   Papillæ of leaves variously divided at the tip 2
2. Leaves ciliate; plants growing on trees .... **T. asprella**
   Leaves not ciliate; plants growing on rocks and earth .... **T. Lescurii**

Thelia hirtella (Hedw.) Sull.

Stumps, roots, and trunks of trees in the woods. Autumn. HARTFORD: Southington, *Nichols.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols.* NEW HAVEN: East Haven (1855), *Eaton;* Madison, *Basye;* New Haven, *J. A. Allen;* Oxford, *Harger;* Woodbridge, *Nichols.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Waterford, *C. B. Graves.*

Ontario and New England to Kansas, south to the Gulf States.

REF. Eaton, **15**, 65. Mrs. Hadley, **41**.

Thelia asprella (Schimp.) Sull.

Stumps, roots, and trunks of trees in the woods. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Hartford, *Miss Lorenz.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: East Haven, *O. D. Allen;* Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1855), *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Norwich, *Setchell.*

Ontario and New England to Florida, west to Minnesota and Texas.

REF. Eaton, **15**, 65.

Thelia Lescurii Sull.

On trap ledges, flat rocks, and dry, sandy soil. Fruit rare, autumn. LITCHFIELD: New Milford, *Nichols*. HARTFORD: Farmington, *Miss Lorenz*. FAIRFIELD: Darien, *Mrs. Lowe*. NEW HAVEN: East Haven, *J. A. Allen;* New Haven (1877), *Eaton;* Oxford, *Harger*. NEW LONDON: Waterford, *C. B. Graves*.

Massachusetts to Missouri, south to the Gulf States.

REF. Eaton, **15**, 65. Grout, **38**. Rau & Hervey, **64**, 52.

Myurella Br. & Sch.

Leaves serrulate, obtuse, rarely short-apiculate.....**M. julacea**
Leaves spinulose-dentate, abruptly long-acuminate..**M. gracilis**

Myurella julacea (Vill.) Br. & Sch.

On rocky banks and in shady fissures of rocks, especially limestone, in mountainous or hilly districts. Fruit rare, July-Aug. NEW HAVEN: Branford and Woodbridge (1880), *J. A. Allen*.

Arctic America, Canada, and the northern United States; Europe; Asia.

Myurella gracilis (Weinm.) Lindb. *M. Careyana*. Sull.

Crevices of moist rocks, usually limestone, in mountainous or hilly regions. Fruit rare, spring. LITCHFIELD: Norfolk (1903), *Miss Lorenz;* Salisbury, *Evans*. HARTFORD: Windsor, *Miss Lorenz*. FAIRFIELD: Sherman, *Nichols*.

Nova Scotia to Minnesota, south to North Carolina; Europe; Asia.

Haplohymenium Doz. & Molk.

Haplohymenium triste (Cesati) Kindb. *Leskea tristis* Cesati. *Anomodon tristis* Sull.

On steep sunny rocks and at the base of trees. Not yet found fruiting in North America. LITCHFIELD: New Milford, *Nichols*. NEW HAVEN: East Haven (1856), Hamden, and New Haven, *Eaton;* North Branford, *Evans;* Woodbridge, *Eaton*.

Eastern United States; Europe; Asia.

REF. Eaton, **15**, 65.

Anomodon Hook. & Tayl.

1. Upper half of leaves lingulate, obtuse or short-apiculate, leaves spreading when moist........................... 2
   Upper half of leaves more or less tapering............... 3
2. Leaves apiculate and with large auricles at the base.... **A. apiculatus**
   Leaves rounded at apex, base not auriculate........**A. minor**
3. Leaves blunt, apiculate, subsecund; branches tapering.... **A. attenuatus**
   Leaves narrowly acuminate, spreading when moist; branches blunt ....**A. rostratus**

Anomodon apiculatus Br. & Sch.

On shaded rocks and at the base of trees. Autumn. LITCHFIELD: Salisbury (1900), *Gilman.*

Ontario and New England, south to Georgia; Europe; Asia.

Anomodon minor (Beauv.) Fürn. *A. obtusifolius* Br. & Sch.

On trees and rocks in the woods. Fruit rare, autumn. LITCHFIELD: Salisbury, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols.* NEW HAVEN: Cheshire, *Evans;* Orange (1875), *Eaton;* Oxford, *Harger.*

New Brunswick to South Dakota, south to Virginia; Asia.

REF. Chamberlain, **12**, 78. Eaton, **15**, 65.

Anomodon attenuatus (Schreb.) Hüben.

Rocks, stumps, and trees in the woods. Autumn. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls and Cheshire, *Nichols;* Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1856), *Eaton;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Newfoundland to Florida, west to British Columbia and Kansas; Cuba; Europe; Asia.

REF. Eaton, **15**, 65.

Anomodon rostratus (Hedw.) Schimp.

At the base of trees and on rocks in the woods. Autumn. LITCHFIELD: Cornwall, *Brewster;* New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Farmington, *Mrs. Lowe;* Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Sherman, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *J. A. Allen;* Meriden, *Nichols;* New Haven (1855), *Eaton;* Woodbridge, *Nichols.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: North Stonington, *C. B. Graves.*

Canada to the Gulf of Mexico; Europe; Asia.

REF. Eaton, **15**, 65. Mrs. Hadley, **42.**

Leskea Hedw.

Leaves ovate-oblong, obtuse, not plicate........... **L. obscura**
Leaves ovate-lanceolate, acute to acuminate, biplicate.... **L. polycarpa**

Leskea polycarpa Ehrh.

On roots and stones, trunks of trees, and decaying wood in wet places. May-June. TOLLAND: Ellington, *Pease.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: New Haven, *Eaton;* Oxford, *Harger;* Wallingford (1878), *Barron.* NEW LONDON: New London, *Spaulding.*

Newfoundland to British Columbia, and southward; Europe; Asia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 192[c].

REF. Eaton, **15**, 65.

Leskea obscura Hedw.

Roots of trees, stones, and logs subject to inundation. May-June. LITCHFIELD: Salisbury, *Nichols;* Woodbury, *Eaton.* HARTFORD: Farmington, *Mrs. Lowe;* Hartford, *Miss Lorenz.* TOLLAND: Vernon, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven, *Nichols;* Hamden, *O. D. Allen;* New Haven (1874), *Eaton;* North Haven, *Nichols;* Wallingford, *Barron.* MIDDLESEX: Killingworth and Portland, *Nichols.* NEW LONDON: New London, *C. B. Graves.*

New Brunswick, Ontario, and the United States east of the Rocky Mountains; Japan.

REF. Eaton, 15, 65.

Rauia Aust.

Rauia scita (Beauv.) Aust. *Hypnum scitum* Beauv. *Thuidium scitum* Aust.

At the base of trees and on stones in the woods. Autumn. TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Hamden and New Haven, *J. A. Allen;* Orange, *Eaton;* Wallingford, *Barron;* Woodbridge (1866), *Eaton.*

Ontario and New England, south to North Carolina and Missouri.

REF. Eaton, 15, 65.

Haplocladium C. Müll.

Stem leaves roundish-ovate, abruptly short-acuminate.... **H. virginianum**
Stem leaves ovate, gradually acuminate...... **H. microphyllum**

Haplocladium virginianum (Brid.) Broth. *Hypnum gracile* var. *lancastriense* Sull. & Lesq. *Thuidium virginianum* Lindb.

On the ground in open woods. May-June. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls and Meriden, *Nichols;* New Haven (1876), *Pease;* Orange, *Nichols;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Montville, *C. B. Graves.*

Massachusetts to Wisconsin, south to Mexico; Europe.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 172 (as *Thuidium virginianum*).

REF. Mrs. Lowe, 55; 58.

Haplocladium microphyllum (Sw.) Broth. *Hypnum gracile* Br. & Sch. *Thuidium gracile* Br. & Sch. *T. microphyllum* Best.

On rotten wood, bases of trees, stones, and the ground. Summer. NEW HAVEN: Woodbridge (1879), *J. A. Allen.*

New Brunswick to British Columbia, and southward to the Gulf of Mexico; Cuba; Jamaica; Europe; Asia.

REF. Limpricht, 51[2], 828.

Claopodium (Lesq. & James) Ren. & Card.

Claopodium pellucinerve (Mitt.) Best.

"On an old log in a swamp." FAIRFIELD: Darien (1903), *Mrs. Lowe.*

Known from but two other localities — North India and Yukon Territory.

REF. Miss Wheeler, 80.

Thuidium Br. & Sch.

1. Monoicous; plants small 2
   Dioicous; plants large, stems 6-10 cm. long 3
2. Stem 1-2 cm. long; branches papillose .... **T. pygmæum**
   Stem 2-4 cm. long; branches smooth .... **T. minutulum**
3. Stem pinnately branched; plants ascending ...... **T. abietinum**
   Stems mostly bipinnately branched; plants prostrate 4
4. Stem leaves abruptly acuminate, margin plane, midrib percurrent; perichætial leaves not ciliate .... **T. recognitum**
   Margin of stem leaves revolute, midrib vanishing below the apex 5
5. Branches densely paraphyllose; stem leaves gradually acuminate, coarsely papillose; perichætial leaves ciliate **T. delicatulum**
   Branches with few or no paraphyllia; stem leaves minutely papillose; perichætial leaves not ciliate .... **T. Alleni**

Thuidium pygmæum Br. & Sch. *Hypnum pygmæum* Sull.

Rocks or earth in the woods. Summer. NEW HAVEN: Cheshire (1879), *J. A. Allen.*

New England to Ohio; Canada; Asia.

Thuidium minutulum (Hedw.) Br. & Sch. *Hypnum minutulum* Hedw.

At the base of trees and on rotten logs in the woods. Autumn. NEW HAVEN: New Haven (1855) and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Evans.*

New Brunswick to Minnesota, south to Florida and Mexico; Europe.

REF. Eaton, 15, 65.

Thuidium recognitum (Hedw.) Lindb. *Hypnum recognitum* Hedw.

On the ground, rotten wood, and rocks in moist woods. Nov.-Dec. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Hartford, *Mrs. Lowe.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: East Haven (1855), *Eaton;* Hamden, *J. A. Allen.* MIDDLESEX: Killingworth, *Nichols.*

Labrador to Yukon Territory, south in the east to Florida; Europe; Asia; Africa.

Thuidium delicatulum (L.) Br. & Sch. *Hypnum delicatulum* L.

On the ground, rocks, and rotten wood in moist woods. Nov.-Dec. LITCHFIELD: New Milford, *Nichols;* Norfolk, *Eaton;* Salisbury, *Gilman.* HARTFORD: Burlington, *Nichols;* West Hartford, *Miss Lorenz.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe.* NEW HAVEN: East Haven and Hamden, *Eaton;* Madison, *Nichols;* New Haven, *J. A. Allen;* Orange, *Evans;* Oxford, *Harger;* Woodbridge (1875), *Eaton.* MIDDLESEX: Chester and Killingworth, *Nichols.* NEW LONDON: North Stonington and Waterford, *C. B. Graves.*

Labrador to the Rocky Mountains, south to the Gulf States and Mexico; West Indies; Central and South America; Europe; Asia.

REF. Eaton, 15, 65. Mrs. Lowe, 59.

Thuidium Alleni Aust. *Hypnum Alleni* Lesq. & James.

Peat bogs. Mature sporophyte unknown. NEW HAVEN: New Haven (1880), *J. A. Allen.*

Connecticut to Louisiana.

REF. Austin, 4, 15, 16. Grout, 37, 240. Lesquereux &

James, **50**, 327. Paris, **61**, 275; **62**[5], 3. Rau & Hervey, **64**, 52. Renauld & Cardot, **65**, 16.

Thuidium abietinum (L.) Br. & Sch. *Hypnum abietinum* L.

On rocks and the ground in dry, open woods, especially in calcareous districts. Spring; not yet found fruiting in the eastern United States. LITCHFIELD: Salisbury (1907), *Nichols.*

Greenland to Virginia, westward to Alaska and the Rocky Mountains; Europe; Asia.

Elodium (Sull.) Warnst.

Elodium paludosum (Sull.) Loeske. *Hypnum paludosum* Sull. *Thuidium paludosum* Jaeg. & Sauerb.

On the ground in swamps and bogs. June. HARTFORD: Canton, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Nichols.* NEW HAVEN: East Haven, *O. D. Allen;* Hamden and New Haven (1856), *Eaton;* Orange, *Evans;* Woodbridge, *Eaton.* MIDDLESEX: Chester, *J. A. Allen;* Middlefield, *Evans;* Saybrook, *Eaton.*

Ontario and New England, south to Delaware and Illinois; Asia.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 156 (as *Thuidium paludosum*).

REF. Eaton, **15**, 66. Mrs. Hadley, **40**. Mrs. Lowe, **58**. Rau, **63**, 152.

FAMILY HYPNACEÆ

Camptothecium Br. & Sch.

Camptothecium nitens (Schreb.) Schimp. *Hypnum nitens* Schreb.

Swamps, bogs, and wet meadows. May-June. HARTFORD: Berlin (1875), *Coleman.*

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, **15**, 66.

Brachythecium Br. & Sch.

1. Stalk smooth throughout 2
   Stalk more or less roughened........ 5
2. Dioicous 3
   Monoicous 4
3. Capsules erect and symmetrical........**B. acuminatum**
   Capsules unsymmetrical, more or less inclined..**B. oxycladon**
4. Stem leaves gradually narrowed from base to slender apex ....**B. acutum**
   Stem leaves ovate-lanceolate........**B. salebrosum**
5. Stalk rough above, nearly smooth below; monoicous...... 6
   Stalk rough throughout with large, crowded papillæ...... 8
6. Midrib extending nearly to apex of leaf........**B. populeum**
   Midrib extending to middle of leaf or a little beyond.... 7
7. Cilia appendiculate ....**B. plumosum**
   Cilia not appendiculate ....**B. campestre**
8. Dioicous 9
   Monoicous 10
9. Cells of branch leaves about 5 times as long as broad, unipapillate ....**B. Novæ-Angliæ**
   Cells of branch leaves at least 8 times as long as broad, smooth ....**B. rivulare**
10. Stem leaves lanceolate; cilia not appendiculate..**B. velutinum**
    Stem leaves ovate to triangular-ovate........ 11
11. Cilia not appendiculate ....**B. Rutabulum**
    Cilia appendiculate ....**B. Starkei**

Brachythecium salebrosum (Hoffm.) Br. & Sch. *Hypnum salebrosum* Hoffm.

On rocks and earth, trunks and roots of trees, and decaying wood, in moist shaded places, especially in pine or hemlock woods. Autumn. HARTFORD: Farmington, *Mrs. Lowe.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Cheshire and East Haven, *Nichols;* Guilford, Hamden, and New Haven (1856), *Eaton;* North Haven, *Harger;* Orange, *Nichols;* Woodbridge, *Evans.* NEW LONDON: North Stonington, *C. B. Graves.*

Arctic America, Canada, and southward to South Carolina and Missouri; Europe; Asia; Africa.

REF. Eaton, 15, 66.

Brachythecium campestre (C. Müll.) Br. & Sch. *Hypnum campestre* Bruch.

Wet non-calcareous rocks, moist banks, or decaying logs. Winter. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: Hamden (1876), *Pease;* New Haven, *Eaton;* North Branford, *J. A. Allen*. NEW LONDON: New London, *C. B. Graves*.

Canada and the northern United States, south to the mountains of Alabama and Colorado; Europe; Asia; Africa.

REF. Eaton, **15**, 66.

Brachythecium acutum (Mitt.) Sull. *Hypnum acutum* Mitt.

On rotten logs and earth in moist places. Autumn. NEW HAVEN: New Haven (1875), *Pease*.

Canada and the northern United States, south to Arkansas.

Brachythecium oxycladon (Brid.) Jaeg. & Sauerb. *Hypnum lætum* Brid. *Brachythecium lætum* Br. & Sch.

Earth, rocks, and roots of trees in open woods. Autumn. LITCHFIELD: New Milford, *Nichols*; Salisbury, *Evans*. TOLLAND: Somers, *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, Sherman, and Stratford, *Nichols*. NEW HAVEN: Cheshire (1856), *Eaton;* Hamden, *J. A. Allen;* New Haven and Orange, *Eaton;* Woodbridge, *Nichols*. MIDDLESEX: Killingworth, *Nichols;* Saybrook, *Eaton*. NEW LONDON: Waterford, *C. B. Graves*.

Newfoundland to Florida, westward to the Rocky Mountains; Europe.

REF. Eaton, **15**, 66.

Brachythecium Rutabulum (L.) Br. & Sch. *Hypnum Rutabulum* L.

Earth, stones, trees, and rotting wood in shaded places. Winter. LITCHFIELD: Salisbury, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Sherman, *Nichols*. NEW HAVEN: Cheshire, *Nichols;* Hamden, *J. A. Allen;* New Haven (1855), *Eaton;* Oxford, *Harger*.

MIDDLESEX: Saybrook, *Eaton*. NEW LONDON: New London, *C. B. Graves*.

Newfoundland to Michigan, south to Maryland and Missouri, and on the Pacific slope; Greenland; Europe; Asia; Africa.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 66. Renauld & Cardot, Musci Amer. Sept. No. 243.

REF. Eaton, 15, 66.

Brachythecium rivulare Br. & Sch. *Hypnum rivulare* Bruch.

Wet rocks in brooks, swamps, and ravines. Winter. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Burlington, *Nichols;* Hartford, *Mrs. Lowe*. TOLLAND: Bolton, *Nichols*. WINDHAM: Windham, *Nichols*. NEW HAVEN: Beacon Falls, *Nichols;* Bethany (1876), *Eaton;* Cheshire, *Nichols;* Hamden, *J. A. Allen;* Woodbridge, *Brewster*.

Northern North America, south to North Carolina and Missouri; Europe; Asia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 244.

REF. Eaton, 15, 66.

Brachythecium acuminatum (Hedw.) Kindb. *Hypnum acuminatum* Beauv.

On roots of trees, decaying logs, and rocks in moist woods. Autumn. LITCHFIELD: Salisbury, *Gilman*. NEW HAVEN: Orange (1889), *Eaton*.

Nova Scotia to Minnesota and Colorado, south to the Gulf States.

Brachythecium plumosum (Sw.) Br. & Sch. *Hypnum plumosum* Sw.

Wet non-calcareous rocks in brooks. Autumn. LITCHFIELD: Salisbury, *Gilman*. TOLLAND: Stafford and Vernon, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols*. FAIRFIELD: Darien and Norwalk, *Mrs. Lowe*. NEW HAVEN: Beacon Falls, *Nichols;* Cheshire, *Eaton;* Derby and Hamden, *O. D. Allen;* New Haven (1855), *Eaton;* Orange, *Evans;* Oxford, *Harger;* Woodbridge, *Eaton*. MIDDLESEX:

Killingworth, *Nichols.* NEW LONDON: Waterford, *C. B. Graves.*

Newfoundland to British Columbia, south in the east to Alabama; Europe; Asia; Hawaiian Islands.

REF. Eaton, **15**, 66. Mrs. Lowe, **57**.

Brachythecium populeum (Hedw.) Br. & Sch. ***Hypnum populeum*** Hedw.

Stones, roots, and trunks of trees, in shaded places, especially in pine woods. Winter. WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven (1874), *Young;* Hamden, *O. D. Allen;* Madison, *Nichols;* New Haven, *Eaton.*

Var. **rufescens** Br. & Sch. *Hypnum petrophilum* Funck.

On trap rock. NEW HAVEN: New Haven (1876), *Pease.* The only American locality for the variety.

Nova Scotia to Ontario, south to North Carolina; British Columbia; Europe; Africa.

REF. Eaton **15**, 66. Grout, **34**, 190 (var. *rufescens*).

Brachythecium Starkei (Brid.) Br. & Sch. ***Hypnum Starkei*** Hedw.

At the base of trees, on rotting stumps and earth, in moist mountainous or hilly woods. Winter. FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Woodbridge (1877), *O. D. Allen.*

Arctic America, Canada, and the northern United States; Europe.

Brachythecium Novæ-Angliæ (Sull. & Lesq.) Jaeg. & Sauerb. *Hypnum Novæ-Angliæ* Sull. & Lesq.

On the ground in swamps and wet woods. Winter. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Bolton and Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien and Norwalk, *Mrs. Lowe;* Redding, *Evans.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven, *Evans;* Hamden, *Pease;* Madison, *Nichols;* New Haven (1855), *Eaton;* North Haven, *Nichols;* Orange, *Evans.* MIDDLESEX: Saybrook, *Eaton.* NEW LONDON: Ledyard, *Nichols.*

Canada southward to North Carolina and Missouri; Europe; Asia.

REF. Eaton, **15**, 66.

Brachythecium velutinum (L.) Br. & Sch. *Hypnum velutinum* L.

On earth and rocks, at the base of trees, and on rotting wood. Winter. NEW HAVEN: East Haven, *Evans;* Hamden (1875), *Young;* New Haven, *Eaton.*

Canada and the northern United States; Europe; Asia.

REF. Eaton, **15**, 66.

Cirriphyllum Grout

Stalk smooth	**C. Boscii**
Stalk rough	**C. piliferum**

Cirriphyllum piliferum (Schreb.) Grout. *Hypnum piliferum* Schreb. *Eurynchium piliferum* Br. & Sch.

On the ground and at the base of trees in wet woods and meadows. Fruit rare, autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Farmington, *Mrs. Lowe.* NEW HAVEN: Woodbridge (1876), *O. D. Allen.*

Newfoundland to Maryland and Ohio; Montana to California; Greenland; Europe; Asia.

REF. Eaton, **15**, 66.

Cirriphyllum Boscii (Schwaegr.) Grout. *Hypnum Boscii* Schwaegr. *Eurynchium Boscii* Jaeg. & Sauerb.

On rocks or on the ground in moist open woods. Fruit rare, autumn. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Huntington, *Nichols;* Redding, *Evans;* Sherman, *Nichols.* NEW HAVEN: Derby, *O. D. Allen;* East Haven, Hamden, and Madison, *Nichols;* Meriden, *Miss Lorenz;* New Haven (1855), *Eaton;* Orange, *Evans;* Oxford, *Harger.* MIDDLESEX: Killingworth, *Nichols;* Saybrook, *Eaton.* NEW LONDON: Ledyard, *Nichols;* New London, *C. B. Graves;* Norwich, *Setchell;* Old Lyme, *Eaton.*

Vermont to Florida, westward to Colorado and Arkansas.

REF. Eaton, **15**, 66. Mrs. Hadley, **41**.

Eurynchium Br. & Sch.

1\. Stalk smooth 2
Stalk rough 4
2\. Mosses growing on earth, rocks, or logs in moist woods 3
Mosses growing on wet rocks in brooks or springs...... **E. rusciforme**
3\. Leaves spreading; branches attenuate...........**E. strigosum**
Leaves appressed-imbricated; branches short, julaceous.. **E. diversifolium**
4\. Leaves distinctly papillose; median cells 4-6 times as long as broad ....**E. graminicolor**
Leaves smooth or only slightly papillose; median cells 6-10 times as long as broad.......................**E. hians**

Eurynchium strigosum (Hoffm.) Br. & Sch. *Hypnum strigosum* Hoffm.

Gravelly soil or rocks, roots and old logs, in open woods. Autumn. TOLLAND: Ellington, *Pease.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven, *Eaton;* Hamden, *Pease;* New Haven (1855), *Eaton;* Orange, *Nichols;* Oxford, *Harger;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.*

Arctic America, Canada, and the northern United States; Europe; Asia; Africa.

REF. Eaton, 15, 66.

Eurynchium diversifolium Br. & Sch. *Hypnum diversifolium* Schimp.

Soil and rocks in mountainous woods. Late autumn. FAIRFIELD: Huntington, *Nichols.* NEW HAVEN: East Haven, *Cramer;* Hamden and New Haven (1866), *Eaton.* NEW LONDON: Waterford, *C. B. Graves.*

Ontario and New England to British Columbia, south to Louisiana; Greenland; Europe; Asia.

REF. Eaton, 15, 66.

Eurynchium graminicolor (Brid.) Ren. & Card. *Hypnum Sullivantii* Spruce. *Eurynchium Sullivantii* Jaeg. & Sauerb. *Bryhnia graminicolor* Grout.

On rocks and the ground, rarely on wood, in moist shaded places. Autumn. LITCHFIELD: Canaan and Salisbury, *Nichols.* TOLLAND: Stafford, *Nichols.* NEW HAVEN: Branford and Cheshire (1858), *Eaton;* Derby, *O. D. Allen;* Hamden, *Eaton;* Oxford, *Harger;* Woodbridge, *J. A. Allen.*

New Brunswick to Minnesota, south to Georgia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 196 (as *E. Sullivantii*).

REF. Eaton, **15**, 66. Grout, **35**, 233.

Eurynchium hians (Hedw.) Jaeg. & Sauerb. *Hypnum hians* Hedw.

Moist earth in open woods. Late autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Burlington and Canton, *Nichols;* Manchester, *Cheney.* TOLLAND: Bolton and Stafford, *Nichols.* WINDHAM: Windham, *Nichols.* NEW HAVEN: Cheshire (1855), *Blackman;* East Haven, *Eaton;* Hamden, *J. A. Allen;* Meriden, *Miss Lorenz;* New Haven, *Eaton;* Woodbridge, *Evans.* MIDDLESEX: Killingworth, *Nichols.*

Nova Scotia to British Columbia, south in the east to Alabama; Europe.

REF. Eaton, **15**, 66.

Eurynchium rusciforme (Neck.) Milde. *Hypnum rusciforme* Neck. *Rhynchostegium rusciforme* Br. & Sch.

Dripping rocks and wet stones in brooks. Autumn. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Burlington and Granby, *Nichols.* TOLLAND: Stafford and Vernon, *Nichols.* FAIRFIELD: Monroe, *Miss Lorenz;* Redding, *Evans.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden and New Haven (1856), *Eaton;* Orange, *Evans;* Oxford, *Harger;* Woodbridge, *O. D. Allen.* MIDDLESEX: East Haddam, *C. B. Graves;* Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

Newfoundland to Ontario, south to Georgia, and on the Pacific slope; Europe; Asia; Africa.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 197 (as *Rhynchostegium rusciforme*).

REF. Eaton, **15**, 67.

Rhynchostegium Br. & Sch.

Rhynchostegium serrulatum (Hedw.) Jaeg. & Sauerb. *Hypnum serrulatum* Hedw.

On earth, roots of trees, and logs in the woods. Autumn. LITCHFIELD: New Milford and Salisbury, *Nichols.* HARTFORD: Farmington, *Mrs. Lowe.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, *Nichols;* Norwalk, *Mrs. Lowe.* NEW HAVEN: East Haven, Guilford, and Meriden, *Eaton;* Madison, *Nichols;* New Haven (1855), *Eaton;* Orange, *Evans;* Oxford, *Harger.* MIDDLESEX: Chester and Killingworth, *Nichols.* NEW LONDON: Waterford, *C. B. Graves.*

Newfoundland to Wisconsin, south to the Gulf of Mexico; Alaska; British Columbia.

REF. Eaton, **15**, 67.

Sematophyllum Mitt.

1. Plants growing on wet rocks; monoicous; leaves entire; cilia one or two, short and imperfect........**S. carolinianum**
   Plants growing on trees, decayed logs, or shaded banks; dioicous 2
2. Cilia two, well developed; leaves serrulate at apex........ **S. recurvans**
   Cilia none or rudimentary; leaves sharply serrate at apex **S. tenuirostre**

Sematophyllum recurvans (Michx.) E. G. Britton. *Hypnum recurvans* Beauv. *Rhynchostegium recurvans* Aust.

At the base of trees, on rotten logs, and on the ground, in moist woods, especially in mountainous or hilly regions. Autumn. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Hartford, *Mrs. Lowe.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1855), *Eaton;* Oxford, *Harger;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.*

Var. **squarrosa** (Michx.) E. G. Britton. *Leskea squarrosa* Michx.

NEW HAVEN: New Haven (1890), *Chatterton.*

Newfoundland to Manitoba, south to North Carolina and Missouri; Mexico.

REF. Mrs. E. G. Britton, 10, 61 (var. *squarrosa*). Eaton, 15, 67.

Sematophyllum tenuirostre (Br. & Sch.) E. G. Britton. *Hypnum cylindrocarpum* C. Müll. *Rhynchostegium cylindrocarpum* Aust.

On rocks and decaying logs in the woods. Autumn. NEW HAVEN: Hamden (1878), *J. A. Allen.*

Labrador and Newfoundland, south to Georgia.

REF. Eaton, 15, 67.

Sematophyllum carolinianum (C. Müll.) E. G. Britton. *Hypnum demissum* Wils. var. *carolinianum* Sull. & Lesq.

Wet, non-calcareous rocks in mountain or hill ravines. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Hartford, *Mrs. Lowe.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Orange (1875), *Young;* Woodbridge, *J. A. Allen.* MIDDLESEX: Killingworth, *Nichols.*

Newfoundland to the Gulf States; Asia.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 307 (as *Raphidostegium carolinianum*).

Isopterygium Mitt.

1. Leaves distinctly serrulate, at least in the apical half...... 2
   Leaves entire, or nearly so............................ 3
2. Plants monoicous; leaves serrulate to the middle...... **I. turfaceum**
   Plants dioicous; leaves serrulate to the base..**I. deplanatum**
3. Leaves perfectly entire, without axillary propagula; branchlets tending to become flagelliform at the tips **I. Muellerianum**
   Leaves slightly serrulate at apex, and frequently producing numerous leafy propagula in the axils; branchlets never flagelliform ....**I. elegans**

Isopterygium deplanatum (Schimp.) Jaeg. & Sauerb. *Hypnum deplanatum* Schimp. *Rhynchostegium deplanatum* Sull.

On earth, flat stones, or rotten wood in moist woods.

Fruit rare, autumn. TOLLAND: Stafford, *Nichols*. NEW HAVEN: Cheshire, *Evans;* Hamden (1876), *Pease*.

Nova Scotia to Manitoba, south to Maryland and Missouri.

REF. Eaton, 15, 67.

Isopterygium turfaceum Lindb. *Hypnum turfaceum* Lindb.

In peat bogs or on moist rich soil in the woods. Early summer. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: East Haven, *Nichols;* Woodbridge (1880), *J. A. Allen*.

Canada south to Georgia and Texas; Europe.

Isopterygium Muellerianum (Schimp.) Lindb. *Hypnum Muellerianum* Hook. f.

Moist rocks and earth in mountainous or hilly ravines. Fruit rare, late summer. LITCHFIELD: Salisbury, *Miss Lorenz*. HARTFORD: Manchester, *Miss Lorenz*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1880), *J. A. Allen*. MIDDLESEX: Killingworth, *Nichols*.

New England to North Carolina and Ohio; Europe; Asia.

Isopterygium elegans (Hook.) Lindb. *Hypnum elegans* Hook.

On the ground and rocks in mountainous or hilly woods. Summer. NEW HAVEN: Beacon Falls, *Nichols;* Woodbridge (1879), *J. A. Allen*.

Throughout northern North America, and south along the mountains to Alabama; Europe; Asia.

Plagiothecium Br. & Sch.

1. Leaves equally spreading, alar cells greatly enlarged; branches erect .... **P. striatellum**
   Leaves more or less complanate 2
2. Teeth of peristome not confluent at base and without cross striations on outer surface; cilia lacking...... **P. latebricola**
   Teeth of peristome confluent at base and distinctly transversely striate on outer surface; cilia present.......... 3
3. Monoicous; stems depressed; leaves distinctly complanate, pale green, very glossy.................... **P. denticulatum**
   Dioicous 4

4. Stems depressed; leaves distinctly complanate, acute to acuminate, dark green, scarcely glossy........**P. sylvaticum**
Stems ascending; leaves obscurely complanate or spreading, distinctly acuminate, pale green, glossy...**P. Roeseanum**

Plagiothecium latebricola (Wils.) Br. & Sch. *Hypnum latebricola* Lindb.

Roots, stumps, and hummocks in swamps. Late summer. NEW HAVEN: East Haven (1879), *J. A. Allen.*

Nova Scotia to Ontario, south to Alabama; Europe.

Plagiothecium sylvaticum (Huds.) Br. & Sch. *Hypnum sylvaticum* Huds.

On soil, rocks, and decaying logs in the woods. Summer. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Windham, *Nichols.* NEW HAVEN: Beacon Falls, *Nichols;* Meriden (1856), *Eaton;* North Haven, *Nichols;* Oxford, *Harger;* Woodbridge, *Eaton.* MIDDLESEX: Durham, *Evans.*

Nova Scotia to Minnesota, south to Alabama; Alaska to Oregon; Europe; Asia; Africa.

REF. Eaton, 15, 67.

Plagiothecium Roeseanum Br. & Sch. *Hypnum Sullivantiæ* Schimp.

On earth and stones in swampy woods. Summer. WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven, *J. A. Allen;* New Haven (1876), *Pease.*

Nova Scotia to Alaska and British Columbia, south in the east to Florida; Europe; Asia.

Plagiothecium denticulatum (L.) Br. & Sch. *Hypnum denticulatum* L.

Decayed logs, stones, and humus in moist woods. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Farmington, *Mrs. Lowe;* Southington, *Chamberlain.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls, *Nichols;* Bethany, *Merriam;*

East Haven, *Eaton;* Hamden, *Pease;* New Haven, *J. A. Allen;* North Haven, *Nichols;* Orange (1874), *Young.* MIDDLESEX: Killingworth, *Nichols.*

Var. **lætum** (Br. & Sch.) Lindb.

TOLLAND: Ellington, *Pease.* NEW HAVEN: New Haven (1876) and Woodbridge, *Eaton.*

Arctic America, Canada, and the northern United States, southward along the mountains; South America; Europe; Asia; Africa; New Zealand; Tasmania.

REF. Eaton, **15**, 67.

Plagiothecium striatellum (Brid.) Lindb. *Hypnum Muhlenbeckii* Spruce. *P. Muhlenbeckii* Br. & Sch.

On earth, non-calcareous rocks, and rotten logs in the woods. Summer. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: East Hartford, *Mrs. Lowe.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Easton, *Eames;* Norwalk, *Mrs. Lowe;* Redding, *Evans;* Stratford, *Eames.* NEW HAVEN: Beacon Falls, *Nichols;* East Haven, *J. A. Allen;* Hamden and New Haven (1866), *Eaton.* MIDDLESEX: Durham, *Evans;* Killingworth, *Nichols;* Saybrook, *Eaton.* NEW LONDON: East Lyme, *C. B. Graves;* Ledyard, *Nichols;* Old Lyme and Waterford, *C. B. Graves.*

Greenland and Newfoundland to Minnesota, south to North Carolina; Alaska; Europe.

REF. Eaton, **15**, 67. Mrs. Lowe, **56**.

Amblystegiella Loeske

Plants minute (0.5-1 cm. long); leaves 0.2-0.4 mm. long.. **A. confervoides**

Plants larger (2-4 cm. long); leaves 0.8-1.2 mm. long.. **A. adnata**

Amblystegiella confervoides (Brid.) Loeske. *Hypnum confervoides* Brid.

Shaded limestone ledges. Summer. LITCHFIELD: Salisbury, *Nichols.* FAIRFIELD: Sherman (1906), *Evans.*

New Brunswick to Connecticut and Ohio, westward to the Rocky Mountains; Europe; Asia.

Exsic. Grout, N. Amer. Musci Pleuro. No. 317 (as *Amblystegium confervoides*).

Amblystegiella adnata (Hedw.) Nichols. *Hypnum adnatum* Hedw. *Amblystegium adnatum* Aust.

On rocks and at the base of trees in the woods. Autumn. Litchfield: Salisbury, *Nichols*. Fairfield: Danbury, *Nichols;* Darien, *Mrs. Lowe*. New Haven: East Haven, *Eaton;* Meriden, *Nichols;* New Haven (1875), *Eaton;* Woodbridge, *J. A. Allen*. New London: New London, *C. B. Graves*.

New Brunswick to British Columbia, south to North Carolina and Texas; Asia.

Ref. Eaton, 15, 67.

Amblystegium Br. & Sch.

1. Leaves with a distinct border, midrib joining border at apex .... **A. Lescurii**
   Leaves not bordered 2
2. Midrib extending nearly or quite to apex 3
   Midrib disappearing at the middle or above 6
3. Leaves not acuminate, apex blunt .... **A. fluviatile**
   Leaves acuminate, apex acute 4
4. Basal cells abruptly enlarged .... **A. irriguum**
   Basal cells not enlarged 5
5. Midrib ceasing below apex, 0.024-0.035 mm. wide at base .. **A. varium**
   Midrib commonly strong, excurrent, 0.065-0.225 mm. wide at base .... **A. noterophilum**
6. Cells near middle of leaf 10-15 times as long as broad .... **A. riparium**
   Cells near middle of leaf 8 times as long as broad, or less .. 7
7. Alar cells quadrate or transversely elongated .... **A. serpens**
   Alar cells oblong 8
8. Stem leaves 0.9-1.2 mm. long .... **A. Juratzkanum**
   Stem leaves 1.2-1.6 mm. long .... **A. Kochii**

Amblystegium serpens (L.) Br. & Sch. *Hypnum serpens* L.

On the roots and at the base of trees, on decaying logs, soil, and rocks in moist woods. Early summer. Litchfield:

Salisbury, *Nichols.* HARTFORD: Hartford, *Mrs. Lowe.* TOLLAND: Ellington, *Pease.* NEW HAVEN: Branford and Hamden, *O. D. Allen;* New Haven (1855), *Eaton;* NEW LONDON: Waterford, *C. B. Graves.*

Arctic America to the Gulf of Mexico; found in most parts of the world.

REF. Eaton, **15**, 67.

Amblystegium Juratzkanum Schimp.

Moist stones or earth. Early summer. LITCHFIELD: Salisbury (1905), *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: North Branford, *Evans.*

Temperate North America; Europe; Asia.

Amblystegium varium (Hedw.) Lindb. *Hypnum orthocladon* Brid. *Amblystegium radicale* Br. & Sch. *Hypnum radicale* Wils. *Amblystegium orthocladon* Mac. & Kindb.

On stones, earth, or rotten wood, and at the base of trees in moist woods. Late spring. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Canton, *Nichols;* Windsor, *W. E. Britton.* TOLLAND: Ellington, *Pease;* Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Redding, *Evans.* NEW HAVEN: Cheshire, *Nichols;* East Haven, Hamden, and New Haven, *O. D. Allen;* North Branford, *Evans;* Orange (1874), *Kleeberger.* MIDDLESEX: Chester, *Nichols.* NEW LONDON: Groton, *C. B. Graves.*

Southern Canada to the Gulf of Mexico; Europe.

REF. Eaton, **15**, 67.

Amblystegium irriguum (Wils.) Br. & Sch. *Hypnum irriguum* Wils.

On earth or stones, not on limestone, in wet places, frequently in the water. Late spring. HARTFORD: Hartford and Windsor, *Mrs. Lowe.*

Ontario southward to North Carolina and Missouri; Europe; Asia; Africa.

REF. Mrs. Lowe, **58**.

Amblystegium noterophilum (Sull.) Holzing. *Hypnum irriguum* var. *spinifolium* Lesq. & James.

In or at the margins of springs and streams in calcareous regions. Rarely fruiting; summer. LITCHFIELD: Salisbury, (1907), *Nichols*.

New England to Pennsylvania, westward to Montana and Oregon.

Amblystegium fluviatile (Sw.) Br. & Sch. *Hypnum fluviatile* Sw.

Rocks or earth in and along streams in non-calcareous districts. Early summer. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Berlin, *Coleman;* Plainville and Southington, *Chamberlain*. TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Cheshire, *Eaton;* East Haven, *O. D. Allen;* Hamden, *Nichols;* Meriden (1856), *Eaton;* North Branford, *Evans*. MIDDLESEX: Killingworth, *Nichols*.

Newfoundland to Wisconsin, south to New Jersey and Missouri; Europe.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 246 (as *A. orthocladon*).

REF. Eaton, **15**, 67.

Amblystegium Lescurii (Sull.) Aust. *Hypnum Lescurii* Sull.

Wet rocks in mountain or hill streams. Late spring. TOLLAND: Ellington, *Pease;* Stafford, *Nichols*. NEW HAVEN: Ansonia, *O. D. Allen;* Beacon Falls, *Nichols;* Hamden, *J. A. Allen;* Orange (1874), *Kleeberger*. NEW LONDON: Groton, *C. B. Graves;* Ledyard, *Nichols*.

Ontario and New England, south to Georgia.

Amblystegium riparium (L.) Br. & Sch. *Hypnum riparium* L.

On earth, stones, and roots of trees, in swamps, springs, or running water. Late spring. LITCHFIELD: Litchfield, *Mrs. E. G. Britton;* Salisbury, *Nichols*. HARTFORD: Hartford, *Mrs. Lowe;* Southington, *Nichols*. TOLLAND: Bolton, *Nichols;* Ellington, *Pease*. NEW HAVEN: East Haven, Hamden, and New Haven (1856), *Eaton*. NEW LONDON: Waterford, *C. B. Graves*.

Var. **longifolium** (Schultz) Br. & Sch.

FAIRFIELD: Darien (1903), *Mrs. Lowe.*

Throughout North America, and in most parts of the world.

REF. Eaton, 15, 67.

Amblystegium Kochii Br. & Sch.

On earth in moist woods. Early summer. NEW HAVEN: New Haven (1906), *Nichols.*

Probably throughout temperate North America; Europe; Asia.

Chrysohypnum (Hampe) G. Roth

1. Midrib wanting, or very short and double 2
   Midrib distinct, single 4
2. Monoicous; plants small (1-4 cm. long); leaves finely serrulate all around .... **C. hispidulum**
   Dioicous; plants larger (5-10 cm. long); leaves entire..... 3
3. Stems erect or ascending; leaves gradually acuminate.. **C. stellatum**
   Stems procumbent; leaves suddenly ending in a long piliform acumen .... **C. protensum**
4. Leaves squarrose, alar cells scarcely enlarged.......... **C. chrysophyllum**
   Leaves erect, spreading; alar cells enlarged... **C. polygamum**

Chrysohypnum hispidulum (Brid.) G. Roth. *Hypnum hispidulum* Brid.

Roots of trees, decayed wood, and humus, in wet, swampy woods. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Farmington, *Mrs. Lowe.* TOLLAND: Ellington, *Pease.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Cheshire and East Haven, *Eaton;* Hamden, *J. A. Allen;* Madison, *Nichols;* New Haven (1856), *Eaton;* Orange and Oxford, *Harger.* NEW LONDON: New London and Waterford, *C. B. Graves.*

Canada southward to North Carolina and Missouri; Europe; Asia.

REF. Eaton, 15, 67.

Chrysohypnum chrysophyllum (Brid.) Loeske. *Hypnum chrysophyllum* Brid.

Rocks, earth, roots, and stumps, in moist places. Summer.

LITCHFIELD: Salisbury, *Gilman*. HARTFORD: Farmington, *Mrs. Lowe;* West Hartford, *Miss Lorenz*. TOLLAND: Ellington (1876), *Pease;* Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: East Haven, *Eaton;* Hamden, *O. D. Allen;* New Haven, *Pease;* Orange, *O. D. Allen*. MIDDLESEX: Killingworth, *Nichols*.

Var. **tenellum** Schimp. *Hypnum bergenense* Aust.

NEW HAVEN: Ansonia, *O. D. Allen;* New Haven (1881), *J. A. Allen*.

Canada and the northern United States, south to Louisiana; Europe; Asia.

REF. Eaton, 15, 67.

Chrysohypnum protensum (Brid.) Loeske. *Hypnum stellatum* var. *protensum* Röhl.

On hummocks in swamps, and on the ground in wet places. Fruit rare, summer. NEW HAVEN: Branford, *O. D. Allen;* Cheshire, *Nichols;* New Haven (1880), *J. A. Allen*. NEW LONDON: Norwich, *Hatcher*.

Canada and the northern United States; Europe; Asia.

Chrysohypnum stellatum (Schreb.) Loeske. *Hypnum stellatum* Schreb.

Wet banks and swamps. Summer. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Farmington (1903), *Mrs. Lowe;* West Hartford, *Miss Lorenz*. FAIRFIELD: Danbury, *Nichols*. NEW HAVEN: Meriden, *Miss Lorenz*.

Arctic America, south to Virginia; Europe; Asia.

Chrysohypnum polygamum (Br. & Sch.) Loeske. *Hypnum polygamum* Wils.

Moist sandy places in meadows and swamps. Early summer. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Stratford, *Eames*. NEW HAVEN: Oxford (1890), *Harger*.

Arctic America, Canada, and the northern United States; Europe; Asia.

Cratoneuron (Sull.) G. Roth

Cratoneuron filicinum (L.) G. Roth. *Hypnum filicinum* L.

On wet limestone rocks, frequently in springs or swamps.

Fruit rare, spring. LITCHFIELD: Salisbury (1905), *Nichols.* FAIRFIELD: Sherman, *Nichols.*

Arctic America, Canada, and the northern United States, south to the mountains of Utah; Europe; Asia; Africa.

Rhytidiadelphus (Lindb.) Warnst.

Stem leaves multiplicate, rough at back.......... **R. triquetrus**
Stem leaves not plicate, smooth at back......... **R. squarrosus**

Rhytidiadelphus triquetrus (L.) Warnst. *Hypnum triquetrum* L. *Hylocomium triquetrum* Br. & Sch.

On the ground in swampy or dry woods. Fruit occasional, early spring. LITCHFIELD: Cornwall, *Brewster;* Salisbury, *Nichols.* HARTFORD: Plainville, *Chamberlain;* West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Sherman, *Nichols.* NEW HAVEN: East Haven (1855), *Eaton;* Hamden, *J. A. Allen;* New Haven, *Eaton;* North Branford, *Evans;* Woodbridge, *Eaton.* NEW LONDON: Griswold, *C. B. Graves.*

Arctic America, Canada, and the northern United States; south in the east to North Carolina; Europe; Asia; Africa.

REF. Eaton, **15**, 68.

Rhytidiadelphus squarrosus (L.) Warnst. *Hypnum squarrosum* L.

Meadows and wet grassy places. Fruit rare, spring. NEW HAVEN: Hamden (1880), *J. A. Allen.*

Arctic America, Canada, and the northern United States; Europe; Asia; Azores.

Rhytidium (Sull.) Kindb.

Rhytidium rugosum (Ehrh.) Kindb. *Hypnum rugosum* Ehrh.

In dry grassy places and on sunny rocks, usually calcareous, in mountainous or hilly regions. Fruit very rare, summer. LITCHFIELD: Salisbury, *Mrs. Phelps.* FAIRFIELD: Sherman, *Nichols.* NEW HAVEN: Meriden (1873), *Eaton.*

Arctic America, Canada, and the northern United States; Europe; Asia.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 200.
REF. Eaton, 15, 67.

Hylocomium Br. & Sch.

Stem regularly bi-tripinnate; stem leaves gradually acuminate, not auricled .... **H. splendens**
Stem irregularly pinnate; stem leaves abruptly acuminate, auricled at the base.......................... **H. brevirostre**

Hylocomium splendens (Hedw.) Br. & Sch. *Hypnum splendens* Hedw.

Moist mountain or hill woods. Fruit occasional, spring. LITCHFIELD: Norfolk, *Eaton;* Salisbury, *Gilman.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Newtown, *Harger;* Redding, *Evans.* NEW HAVEN: New Haven (1855), *Eaton;* North Branford, *Miss Bradley;* Woodbridge, *Evans.* NEW LONDON: Ledyard, *C. B. Graves.*

Arctic America, Canada, and the northern United States; Europe; Asia; Africa.

REF. Eaton, 15, 68.

Hylocomium brevirostre (Ehrh.) Br. & Sch. *Hypnum brevirostre* Ehrh.

On rocks and at the base of trees in wet ravines. Spring.

LITCHFIELD: Salisbury, *Gilman.* FAIRFIELD: Monroe, *Miss Lorenz;* Redding, *Evans.* NEW HAVEN: Beacon Falls, *Nichols;* Cheshire and Hamden (1866), *Eaton;* Oxford, *Harger;* Woodbridge, *Eaton.*

Nova Scotia to Ontario, south to North Carolina; Europe; Asia; Africa.

REF. Eaton, 15, 68.

Ctenidium (Schimp.) Mitt.

Ctenidium molluscum (Hedw.) Mitt. *Hypnum molluscum* Hedw.

Moist rocks and earth in mountainous or hilly woods. Fruit occasional, summer. LITCHFIELD: Salisbury, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East

Haven, *Evans;* Hamden (1855), *Eaton.* MIDDLESEX: Killingworth. *Nichols.*

Newfoundland to Georgia, west to the Rocky Mountains; Europe; Asia; Africa.

REF. Eaton, **15**, 67.

Ptilium (Sull.) DeNot.

Ptilium Crista-castrensis (L.) DeNot. *Hypnum Crista-castrensis* L.

On moist earth and rotten logs in mountainous or hilly woods. Fruit occasional, autumn. LITCHFIELD: Cornwall, *Brewster;* Norfolk, *Eaton;* Salisbury, *Nichols.* HARTFORD: Hartford, *Mrs. Lowe.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: East Haven and Hamden, *Eaton;* Oxford, *Harger;* Woodbridge (1875), *Eaton.* NEW LONDON: Groton and Montville, *C. B. Graves;* Norwich, *Setchell;* Preston, *C. B. Graves.*

Arctic America, Canada, and the northern United States, south in the east to North Carolina; Europe; Asia.

REF. Eaton, **15**, 68.

Stereodon (Brid.) Mitt.

1. Alar cells more or less enlarged, often inflated, hyaline or colored 2
   Alar cells quadrate, not enlarged 6
2. Capsule plicate when dry; leaves serrulate above 3
   Capsule not plicate when dry 4
3. Alar cells scarcely inflated, yellow, thick-walled..**S. curvifolius**
   Alar cells inflated, hyaline, thin-walled..........**S. Lindbergii**
4. Capsule suberect; leaves serrulate all around, alar cells orange; paraphyllia numerous ....**S. imponens**
   Capsule cernuous; leaves serrulate only above, alar cells green, hyaline, or yellow-brown; paraphyllia few........ 5
5. Mosses growing on bark or logs in the woods.......**S. fertilis**
   Mosses growing on the ground in swamps.........**S. pratensis**
6. Quadrate cells numerous; midrib absent or very short.... **S. cupressiformis**
   Quadrate cells few; midrib usually reaching to middle of leaf 7

7. Branch leaves long-acuminate, serrulate to near the base **S. pallescens**
Branch leaves subulate to short-acuminate, serrulate only above the middle .... **S. reptilis**

Stereodon fertilis (Sendt.) Lindb. *Hypnum fertile* Sendt.

Rotten logs and stumps in mountainous or hilly woods. Summer. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: Oxford (1888), *Harger*.

Canada and the northern United States, south in the east to Georgia; Europe; Asia.

Stereodon pallescens (Hedw.) Lindb. *Hypnum pallescens* Br. & Sch. *H. Jamesii* Lesq. & James.

On rocks and stumps and at the base of trees in hilly woods. Summer. LITCHFIELD: Salisbury, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. NEW HAVEN: East Haven and Woodbridge (1866), *Eaton*. NEW LONDON: East Lyme, New London, and Waterford, *C. B. Graves*.

Canada and the northern United States, south in the east to North Carolina; Europe; Asia.

REF. Eaton, 15, 67.

Stereodon reptilis (Michx.) Mitt. *Hypnum reptile* Michx.

On roots, logs, and at the base of trees, especially spruce, in mountainous or hilly woods. Autumn. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: Hartford, *Mrs. Lowe*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe*. NEW HAVEN: New Haven (1876), *J. A. Allen;* Orange, *O. D. Allen*. MIDDLESEX: Killingworth, *Nichols*.

Canada south to North Carolina and Utah; Europe; Asia.

REF. Eaton, 15, 67. Mrs. Lowe, 58.

Stereodon imponens (Hedw.) Lindb. *Hypnum imponens* Hedw.

On stones, earth, roots, and stumps in moist woods. Late autumn. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: Canton, *Nichols;* West Hartford, *Miss Lorenz;* Windsor, *W. E.*

Britton. TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *J. A. Allen;* New Haven (1855), *Eaton;* Woodbridge, *O. D. Allen.*

Canada south to Georgia and California; Europe; Asia.

REF. Eaton, **15**, 67.

Stereodon cupressiformis (L.) Lindb. *Hypnum cupressiforme* L.

Rocks, roots, and trunks of trees, in moist woods or wet ravines. Late autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols;* Hartford, *Mrs. Lowe.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Danbury, *Nichols;* Redding, *Evans;* Sherman and Stratford, *Nichols.* NEW HAVEN: Derby, *O. D. Allen;* East Haven, Hamden, and New Haven, *Eaton;* Oxford, *Harger.* MIDDLESEX: Chester and Killingworth, *Nichols.* NEW LONDON: New London, *C. B. Graves.*

Arctic America, Canada, and south to the Gulf States; a cosmopolitan.

REF. Eaton, **15**, 67.

Stereodon Lindbergii (Mitt.) Warnst. *Hypnum Patientiæ* Lindb.

Moist woods, meadows, and swamps. Summer. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien (1903), *Mrs. Lowe.* NEW HAVEN: New Haven, *Nichols.* MIDDLESEX: Killingworth, *Nichols.*

Arctic America, Canada, and the northern United States, south in the east to Florida; Europe; Asia.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 141 (as *H. Patientiæ*).

Stereodon curvifolius (Hedw.) E. G. Britton. *Hypnum curvifolium* Hedw.

On decaying logs, rarely on rocks, in moist woods. Early summer. LITCHFIELD: Salisbury, *Nichols.* TOLLAND: Elling-

ton, *Pease*. WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: Beacon Falls, *Nichols;* Cheshire (1856), *Eaton;* Hamden and New Haven, *J. A. Allen;* North Branford, *Eaton;* Prospect, *Merriam*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Ledyard, *C. B. Graves*.

Arctic America and Canada, southward to Florida and Colorado; Asia.

REF. Eaton, **15**, 67.

Stereodon pratensis (Koch) E. G. Britton. *Hypnum pratense* Koch.

Swampy meadows. Fruit rare, spring. HARTFORD: Windsor, *Miss Lorenz*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Bridgeport, *Eames*. NEW HAVEN: Hamden (1875), *Young;* New Haven, *O. D. Allen;* Orange, *Evans*.

Arctic America, Canada, and the northern United States, south in the east to Florida; Europe; Asia.

Heterophyllon Kindb.

Heterophyllon Haldanianum (Grev.) Kindb. *Hypnum Haldanianum* Grev.

Rocks, earth, and rotten logs in the woods. Autumn. LITCHFIELD: Salisbury, *Nichols*. HARTFORD: Burlington and Canton, *Nichols;* Hartford, *Miss Lorenz*. TOLLAND: Bolton, *Nichols;* Ellington, *Pease*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols;* Darien and Norwalk, *Mrs. Lowe*. NEW HAVEN: Bethany, *Eaton;* East Haven, *Nichols;* Hamden, *Eaton;* Madison, *Nichols;* New Haven (1866), *Williams;* North Haven, *Nichols;* Orange, *Chatterton;* Oxford, *Harger;* Woodbridge, *Eaton*. NEW LONDON: New London, *C. B. Graves*.

Nova Scotia to Montana, and south to Alabama and Missouri; Europe; Asia.

EXSIC. Grout, N. Amer. Musci Pleuro. No. 47[a] (as *Hypnum Haldanianum*). Renauld & Cardot, Musci Amer. Sept. No. 199 (as *H. Haldanianum*).

REF. Eaton, **15**, 68.

Hypnum (Dill.) L.

Hypnum Schreberi Willd.

Dry, open woods, banks, bogs, etc. Fruit occasional, spring. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Canton, *Nichols;* Hartford, *Mrs. Lowe*. TOLLAND: Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Redding, *Evans*. NEW HAVEN: East Haven, *Evans;* Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1866) and Woodbridge, *Eaton*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Groton, *C. B. Graves*.

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, **15**, 68.

Calliergon (Sull.) Kindb.

Plants monoicous (autoicous), sparingly branched; alar cells enlarged, but passing gradually into the normal cells of the leaf.............................**C. cordifolium**

Plants dioicous, profusely branched; alar cells inflated, forming a sharply defined group..............**C. giganteum**

Calliergon giganteum (Schimp.) Kindb. *Hypnum giganteum* Schimp.

Bogs, swamps, and wet places, especially in calcareous districts. Fruit rare, May-June. LITCHFIELD: Salisbury, *Mrs. Phelps*. FAIRFIELD: Danbury (1907), *Nichols*.

Greenland to Pennsylvania and westward to the Pacific coast; Europe; Asia.

Calliergon cordifolium (Hedw.) Kindb. *Hypnum cordifolium* Hedw.

Swamps, marshes, and margins of pools. Fruit rare, summer. LITCHFIELD: Salisbury, *Phelps*. TOLLAND: Stafford, *Nichols*. WINDHAM: Windham, *Nichols*. NEW HAVEN: Hamden, *Eaton;* New Haven, *Nichols;* North Branford, *J. A. Allen;* Orange (1855), *Eaton;* Woodbridge, *Evans*. MIDDLESEX: Saybrook, *Eaton*.

Arctic America, Canada, and the northern United States; Europe; Asia.

REF. Eaton, **15**, 68.

Acrocladium Mitt.

Acrocladium cuspidatum (L.) Lindb. *Hypnum cuspidatum* L.

Swamps, bogs, and wet meadows. Fruit rare, summer. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Berlin, *Coleman.* NEW HAVEN: East Haven, *Eaton;* Meriden, *Miss Lorenz;* New Haven and Orange (1855), *Eaton.*

Canada and the northern United States; Europe; Asia; Africa.

REF. Eaton, 15, 68.

Drepanocladus (C. Müll.) G. Roth

1. Stem with a cortical layer of large, hyaline cells........... 2
   Stem lacking a distinct cortical layer..................... 3
2. Leaves distinctly plicate when moist, and usually minutely serrulate; plants monoicous (autoicous)..........**D. aduncus**
   Leaves not plicate when moist, entire; plants dioicous.. **D. intermedius**
3. Leaves serrulate, at least near the apex; annulus lacking; plants monoicous (autoicous)....................**D. fluitans**
   Leaves entire; annulus distinct; plants dioicous........... 4
4. Alar cells enlarged and forming a well-defined group which extends from the margin of the leaf to the midrib...... **D. Kneiffii**
   Alar cells enlarged, but not extending more than half-way from the margin to the midrib......................... 5
5. Alar cells hyaline, becoming brown with age, and forming a clearly defined group; midrib 0.05-0.06 mm. wide at base ....**D. subaduncus**
   Alar cells yellowish brown, enlarged, but showing a gradual transition into the normal cells of the leaf; midrib 0.07-0.11 mm. wide at base..............**D. Sendtneri**

Drepanocladus Kneiffii (Schimp.) Warnst. *Hypnum aduncum* var. *Kneiffii* Schimp.

Bogs and swamps, often in the water. Fruit rare, May-June. LITCHFIELD: Salisbury (1907), *Nichols.* FAIRFIELD: Danbury, *Nichols.*

Arctic America, Canada, and the northern United States; Europe; Africa.

Drepanocladus subaduncus Warnst. *Hypnum aduncum* var. *gracilescens* Br. & Sch.

Swamps and wet places, especially in limestone regions. Rarely fruiting, May-June. LITCHFIELD: Salisbury (1907), *Nichols*. FAIRFIELD: Danbury, *Nichols*.

Northern North America; Europe.

Drepanocladus Sendtneri (Schimp.) Warnst. var. **giganteus** (Schimp.) Warnst. *Hypnum Sendtneri* Schimp. *H. hamifolium* Schimp.

Swamps and bogs, in the water. May-June; fruit of the variety unknown. HARTFORD: Southington, *Miss Lorenz*. NEW HAVEN: New Haven (1877), *O. D. Allen*.

Arctic America, Canada, and the northern United States, south in the west to Utah; Europe; Asia.

REF. Eaton, **15**, 67. Rau & Hervey, **64**, 45.

Drepanocladus intermedius (Lindb.) Warnst. *Hypnum revolvens* Sw. var. *intermedium* Ren.

Deep swamps. Rarely fruiting, May-June. LITCHFIELD: Salisbury (1907), *Nichols*.

Northern North America; Europe.

Drepanocladus aduncus (L.) Warnst. *Hypnum aduncum* L. *H. uncinatum* Hedw.

Bogs, meadows, and swampy woods. Fruit rare, summer. FAIRFIELD: Stratford, *Nichols*. NEW HAVEN: Bethany, *Eaton;* Branford, *O. D. Allen;* Cheshire, *Harger;* East Haven, New Haven (1855), and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *J. A. Allen*. MIDDLESEX: Durham, *Evans*.

Arctic America, Canada, and the United States, south to North Carolina and Nevada; Europe; Asia.

REF. Eaton, **15**, 67.

Drepanocladus fluitans (L.) Warnst. *Hypnum fluitans* L.

Open swamps and bogs, in the water. Summer. LITCHFIELD: Salisbury, *Nichols*. NEW HAVEN: Hamden, *Evans;* New Haven (1893), *Eaton;* Oxford, *Harger*.

Arctic America, Canada, and the northern United States,

south in the west to Utah; Europe; Asia; Africa; New Zealand.

Hygrohypnum (Lindb.) Loeske

1. Leaves suborbicular; alar cells yellow; midrib faint, short, furcate .... **H. dilatatum**
   Leaves ovate or ovate-lanceolate........................ 2
2. Dioicous; alar cells hyaline or yellowish; midrib reaching middle of leaf or beyond, simple or furcate; perichætial leaves not plicate ....**H. ochraceum**
   Monoicous; alar cells golden yellow to yellow-brown, rarely hyaline; perichætial leaves plicate................ 3
3. Midrib absent, or short and furcate...................... 4
   Midrib single, reaching above middle of leaf......**H. palustre**
4. Leaves broad (2:1), minutely serrulate to the base........ **H. Mackayi**
   Leaves narrower (3:1), serrulate only at the apex.. ...... **H. eugyrium**

Hygrohypnum palustre (Huds.) Loeske. *Hypnum palustre* Huds.

Wet and periodically overflowed stones and rocks, usually calcareous. Summer. NEW LONDON: Montville (1894), *C. B. Graves.*

Canada and the northern United States; Europe; Asia.

Hygrohypnum dilatatum (Wils.) Loeske. *Hypnum molle* of some authors.

On non-calcareous rocks and stones in rapid mountain or hill brooks. Summer. LITCHFIELD: Salisbury, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Ansonia (1880) and Woodbridge, *O. D. Allen.*

Arctic America and Canada, south to North Carolina and Colorado; Europe; Asia.

Hygrohypnum eugyrium (Br. & Sch.) Loeske. *Hypnum eugyrium* Schimp.

On wet non-calcareous rocks in or near mountain or hill brooks. Summer. LITCHFIELD: Salisbury, *Gilman.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1878) and Woodbridge, *J. A. Allen.*

Newfoundland to Alaska, south to Georgia and Colorado; Europe.

Hygrohypnum Mackayi (Schimp.) Loeske.

Shaded stones in hill streams. Summer. NEW HAVEN: Beacon Falls (1907), *Nichols.*

Probably has same range as *H. eugyrium.*

Hygrohypnum ochraceum (Turn.) Loeske. *Hypnum ochraceum* Turn.

On overflowed and wet rocks in rapid mountain or hill streams. Fruit rare, summer. LITCHFIELD: Salisbury, *Evans.* NEW HAVEN: Ansonia, *O. D. Allen;* Beacon Falls, *Nichols;* Hamden (1878), *J. A. Allen.*

Arctic America, Canada, and the northern United States; Europe; Asia.

FAMILY DENDROIDACEÆ

Climacium Web. f. & Mohr

Climacium americanum Brid.

Swamps and wet woods. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Fairfield, *Eames.* NEW HAVEN: Bethany, *Eaton;* East Haven, *Nichols;* Hamden, *Eaton;* Madison, *Nichols;* Milford and New Haven (1855), *Eaton;* Orange, *Evans;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols;* Middlefield, *Evans.* NEW LONDON: New London, *C. B. Graves.*

Var. **Kindbergii** Ren. & Card. *Climacium Kindbergii* Grout.

In wetter places than the typical form, frequently in the water. TOLLAND: Willington, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Stratford, *Nichols.* NEW HAVEN: East Haven, *Nichols;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth and Old Lyme, *Nichols.* NEW LONDON: Groton, Montville, and Waterford (1884), *C. B. Graves.*

New Brunswick to Alabama, west to the Rocky Mountains.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. 238 (var. *Kindbergii*).

REF. Eaton, **15**, 66. Grout, **34**, 161 (var. *Kindbergii*). Young, **81**, 62.

Thamnium Br. & Sch.

Thamnium alleghaniense (C. Müll.) Br. & Sch. *Hypnum alleghaniense* C. Müll.

Dripping overhanging rocks along mountain and hill streams. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: West Hartford, *Miss Lorenz.* NEW HAVEN: Cheshire (1856), *Eaton;* Derby, *O. D. Allen;* Hamden, *Eaton;* New Haven, *J. A. Allen;* Oxford, *Harger;* Woodbridge, *Eaton.* NEW LONDON: Montville and Waterford, *C. B. Graves.*

Nova Scotia to Minnesota, south to the Gulf States.

REF. Eaton, **15**, 67.

FAMILY WEBERACEÆ

Webera Ehrh.

Webera sessilis (Schmid.) Lindb. *Diphyscium foliosum* Mohr.

Moist, shaded earth and banks. Summer. LITCHFIELD: New Milford, *Nichols;* Salisbury, *Gilman.* HARTFORD: Hartford, *Mrs. Lowe;* Southington, *Chamberlain;* West Hartford, *Miss Lorenz.* TOLLAND: Bolton, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols.* FAIRFIELD: Danbury and Huntington, *Nichols;* Redding, *Evans.* NEW HAVEN: Ansonia, *O. D. Allen;* Beacon Falls, *Nichols;* Meriden, *Nichols;* New Haven (1855), Orange, and Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Montville, *C. B. Graves.*

Nova Scotia to Ontario, south to Alabama; Europe; Asia; Madeira Islands.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 121[a] (as *Diphyscium foliosum*).

REF. Collins, **14**, 131. Eaton, **15**, 64.

FAMILY BUXBAUMIACEÆ

Buxbaumia Haller

Buxbaumia aphylla L.

Clayey banks and turfy soil in open woods. Spring. LITCHFIELD: Salisbury, *Evans*. HARTFORD: Canton, *Nichols;* Manchester, *Miss Lorenz*. FAIRFIELD: Darien, *Mrs. Lowe*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden (1866), *Williams;* New Haven, *J. A. Allen;* Oxford, *Harger;* Woodbridge, *Nichols*.

Nova Scotia to Ontario and West Virginia; Yukon Territory to Washington; Europe; Asia.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 250.

REF. Collins, **14**, 131. Eaton, **15**, 64; **17**, 126.

FAMILY GEORGIACEÆ

Georgia Ehrh.

Georgia pellucida (L.) Rabenh. *Tetraphis pellucida* Hedw.

Rotten stumps, roots, and banks in the woods. Spring. LITCHFIELD: Litchfield, *Harris;* Salisbury, *Gilman*. HARTFORD: Hartford and Manchester, *Miss Lorenz;* Windsor, *W. E. Britton*. TOLLAND: Bolton and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Darien, *Mrs. Lowe;* Redding, *Evans*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *Evans;* New Haven (1866), *Eaton;* North Branford, *Evans;* North Haven, *Nichols;* Orange and Woodbridge, *Eaton*. NEW LONDON: East Lyme and Groton, *C. B. Graves*.

Canada and the northern United States; Europe; Asia.

REF. Collins, **14**, 131. Eaton, **15**, 63.

FAMILY POLYTRICHACEÆ

Catharinæa Ehrh.

1. Leaf cells distinctly papillose.................... **C. Macmillani**
   Leaf cells smooth, not papillose.......................... 2
2. Leaves strongly undulate, serrate nearly to base; capsules borne singly or in small clusters................ **C. undulata**
   Leaves scarcely, if at all, undulate, serrate only above middle; capsules borne singly.......................... 3

3. Plants rarely 5 cm. high; midrib and lamina sharply toothed at back, lamellæ 4-8 .... **C. angustata**
Sterile plants 5-10 cm. high; midrib and lamina smooth at back; lamellæ 1-4 .... **C. crispa**

Catharinæa undulata (L.) Web. f. & Mohr. *Atrichum undulatum* Beauv.

Moist, sandy soil in open woods. Autumn. LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Burlington, *Nichols;* West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Lowe;* Windham, *Nichols.* FAIRFIELD: Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *Eaton;* Madison, *Nichols;* New Haven (1855), *Eaton;* North Haven, *Nichols;* Orange, *Evans;* Woodbridge, *O. D. Allen.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* Montville and Waterford, *C. B. Graves.*

Throughout temperate North America; Europe; Asia; Africa.

REF. Collins, **14**, 131. Eaton, **15**, 64. Miss Lorenz, **53**, 46, 47.

Catharinæa Macmillani Holzing.

In dry, exposed situations. Autumn. HARTFORD: Burlington, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* NEW HAVEN: New Haven, North Haven (1907), and Orange, *Nichols.* NEW LONDON: Ledyard, *Nichols.*

New England to Minnesota and Missouri; range not definitely known.

REF. Chamberlain, **13**, 100.

Catharinæa crispa James. *Atrichum crispum* James.

Grassy banks of streams, and in wet sandy soil. Autumn. HARTFORD: East Hartford, *Weatherby.*

Probably throughout Canada and the northern United States; Europe.

REF. Miss Lorenz, **53**, 46, 47.

Catharinæa angustata Brid. *Atrichum angustatum* Br. & Sch.

Clayey banks and sandy soil in open woods. Autumn.

LITCHFIELD: Salisbury, *Nichols.* HARTFORD: Canton, *Nichols;* Southington, *Chamberlain;* West Hartford, *Miss Lorenz.* TOLLAND: Bolton and Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Huntington and Sherman, *Nichols.* NEW HAVEN: East Haven (1855), *Eaton;* Hamden, *Harger;* Madison, *Nichols;* New Haven, *Eaton;* Orange, *Evans;* Woodbridge, *Eaton.* NEW LONDON: North Stonington and Waterford, *C. B. Graves.*

Throughout temperate North America; Europe; Asia.

REF. Collins, **14**, 131. Eaton, **15**, 64. Miss Lorenz, **53**, 46, 47.

Pogonatum Beauv.

Pogonatum tenue (Menz.) E. G. Britton. *P. brevicaule* (Brid.) Beauv. *P. pennsylvanicum* (Hedw.) Par.

Clay banks and roadsides in open woods. Autumn. LITCHFIELD: Salisbury, *Mrs. Phelps.* HARTFORD: Canton, *Nichols;* Hartford, *Mrs. Lowe;* West Hartford, *Miss Lorenz.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe.* NEW HAVEN: Beacon Falls and Cheshire, *Nichols;* Hamden, *J. A. Allen;* New Haven (1866), and Orange, *Eaton;* Oxford, *Harger;* Woodbridge, *Eaton.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* Waterford, *C. B. Graves.*

Nova Scotia to Alabama, and west to Missouri.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. **123** (as *P. pennsylvanicum*).

REF. Collins, **14**, 131. Eaton, **15**, 64. Mrs. Lowe, **59**.

Polytrichum (Dill.) L.

1. Epidermis of capsule with a large pit in the outer wall of each cell, neck distinctly marked off by a constriction; capsule little longer than broad 3
   Epidermis of capsule not pitted, neck indistinctly defined; capsule much longer than broad 2
2. Capsule cylindrical .... **P. alpinum**
   Capsule prismatic .... **P. ohioense**

3. Leaves awned, margins entire, inflexed.................. 4
Leaves pointed, margins sharply serrate, not inflexed..... **P. commune**
4. Awn long and hyaline............................**P. piliferum**
Awn short and red, rarely colorless at the point........... 5
5. Stem densely tomentose, leaves erect...............**P. strictum**
Stem not tomentose, leaves spreading..........**P. juniperinum**

Polytrichum alpinum L. var. **arcticum** (Sw.) Wahl. *Pogonatum alpinum* Röhl. var. *arcticum* Brid.

Stony and grassy mountain slopes. Summer. LITCHFIELD: Salisbury (1906), *Collins.*

Throughout northern North America; Europe.

Polytrichum ohioense Ren. & Card. *P. formosum* of some authors.

On the ground and on earth-covered rocks in moist woods. Summer. LITCHFIELD: Salisbury, *Gilman.* HARTFORD: Hartford, *Miss Lorenz;* Plainville, *Chamberlain;* Windsor, *Rorer.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Danbury, *Eaton;* Darien, *Mrs. Lowe.* NEW HAVEN: East Haven (1856), *Eaton;* Madison, *Nichols;* New Haven, *J. A. Allen;* North Haven and Orange, *Nichols.* MIDDLESEX: Chester, *Nichols;* Durham, *Evans;* Killingworth, *Nichols.* NEW LONDON: Griswold, *Harger;* Montville and New London, *C. B. Graves;* Waterford, *Miss Lorenz.*

Newfoundland to Alaska, south to Alabama, Missouri, and Oregon; Europe.

EXSIC. Holzinger, Musci Acro. Bor.-Amer. No. 124.

REF. Collins, **14**, 131. Eaton, **15**, 64.

Polytrichum piliferum Schreb.

Rocky ridges and gravelly banks in hilly regions. Summer. LITCHFIELD: New Milford and Salisbury, *Nichols.* HARTFORD: Hartford, *Miss Lorenz;* Plainville, *Chamberlain.* TOLLAND: Stafford, *Nichols.* WINDHAM: Canterbury, *Mrs. Hadley.* FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, *Nichols.* NEW HAVEN: Beacon Falls, Madison, and Meriden, *Nichols;* New Haven (1854), *Eaton;* Woodbridge, *Harger.* MIDDLESEX: Killingworth, *Nichols.* NEW LONDON: Ledyard, *Nichols;* Lyme, *Eaton;* Old Lyme, *C. B. Graves.*

Northern North America and southward to Alabama and California: found in most quarters of the globe.

REF. Collins, **14**, 131. Eaton, **15**, 64.

Polytrichum juniperinum Willd.

In dry pastures or open woods in mountainous or hilly regions. Summer. LITCHFIELD: Salisbury, *Gilman*. HARTFORD: Hartford, *Miss Lorenz;* Southington, *Chamberlain*. TOLLAND: Bolton and Ellington, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley*. FAIRFIELD: Danbury, *Nichols;* Darien, *Mrs. Lowe;* Huntington, *Nichols*. NEW HAVEN: Branford, *Ward;* Hamden, *J. A. Allen;* New Haven (1865), *Eaton*. MIDDLESEX: Killingworth, *Nichols*.

Arctic and temperate North America; a cosmopolitan.

REF. Collins, **14**, 131. Eaton, **15**, 64.

Polytrichum strictum Banks.

In peat bogs and wet woods. Summer. NEW HAVEN: Orange (1874), *Young*.

Arctic America, Canada, and the northern United States; South America; Europe; Asia.

REF. Collins, **14**, 131. Eaton, **15**, 64.

Polytrichum commune L.

In pastures and clearings and along the borders of woods and roadsides. Summer. LITCHFIELD: New Milford and Salisbury, *Nichols*. HARTFORD: Hartford, *Miss Lorenz;* Windsor, *Rorer*. TOLLAND: Bolton and Stafford, *Nichols*. WINDHAM: Canterbury, *Mrs. Hadley;* Windham, *Nichols*. FAIRFIELD: Darien, *Mrs. Lowe;* Huntington, Sherman, and Stratford, *Nichols*. NEW HAVEN: Beacon Falls, *Nichols;* Hamden, *Eaton;* Meriden, *Nichols;* New Haven (1856) and Orange, *Eaton;* Oxford, *Harger*. MIDDLESEX: Killingworth, *Nichols*. NEW LONDON: Ledyard, *Nichols;* New London and Waterford, *C. B. Graves*.

Throughout North America; a cosmopolitan.

EXSIC. Renauld & Cardot, Musci Amer. Sept. No. *227*.

REF. Collins, **14**, 131. Eaton, **15**, 64.

SUMMARY

An analysis of the bryophytic flora of Connecticut brings out the interesting fact that only about 18 per cent. of the species are peculiar to America. Over 62 per cent., on the other hand, are common to Europe and Asia, a proportion which is sure to be increased when the Asiatic flora has been more thoroughly explored. Of the remaining species 16 per cent. have been found in Europe but not in Asia, while 4 per cent. have been found in Asia but not in Europe. These relationships may be clearly shown by the following table, in which the species are arranged by orders. One species of Sphagnum which is common to Africa (but not to either Europe or Asia), is included in the first column.

	Peculiar to America.	Common to Europe and Asia.	Common to Europe (but not to Asia).	Common to Asia (but not to Europe).	Total.
Marchantiales	3	9	0	0	12
Jungermanniales	17	62	12	1	92
Anthocerotales	0	1	2	0	3
Sphagnales	2	17	12	0	31
Andreæales	0	1	1	0	2
Bryales	46	154	34	13	247
Total	68	244	61	14	387

The table shows also that about 3 per cent. of our species are Marchantiales, about 23 per cent. Jungermanniales, less than 1 per cent. Anthocerotales, about 8 per cent. Sphagnales, less than 1 per cent. Andreæales, and about 64 per cent. Bryales.

The following table, based on the specimens at hand, gives some idea of the extent to which Connecticut has been explored for Bryophytes. Such a table is merely of historical interest. The discrepancies which apparently exist between the moss floras of the different counties are largely of a temporary nature, and will become less as the exploration of

the state proceeds. There is little probability, for example, that New Haven County is richer in Bryophytes than New London County. It simply represents the part of the state where bryologists have been most numerous and active.

	Litchfield.	Hartford.	Tolland.	Windham.	Fairfield.	New Haven.	Middlesex.	New London.	Common to the eight counties.
Marchantiales .	8	9	4	3	8	12	6	2	1
Jungermanniales .	58	32	31	22	38	81	35	12	4
Anthocerotales .	3	0	0	1	0	3	3	2	0
Sphagnales . .	16	2	9	4	3	25	2	5	0
Andreæales . .	1	1	0	0	0	2	0	0	0
Bryales . . .	157	112	98	108	111	223	90	91	31
Total . .	243	156	142	138	160	346	136	112	36

The last column shows the comparatively small number of species known from each county of the state. All of these species are exceedingly common, and the present figures will probably be soon increased by the addition of other species which must be equally common. Even the majority of the species which are known at present from only one or two localities in the state are undoubtedly much more widely distributed than these scanty records would seem to indicate.

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Publication

Approved by

The Board of Control

The Case, Lockwood & Brainard Company, Hartford, Conn.

THIRD BIENNIAL REPORT OF THE COMMISSIONERS

OF THE

State Geological and Natural History Survey of Connecticut

1907-1908

HARTFORD
Published by the State
1908

HARTFORD, CONN., December 31, 1908.

HIS EXCELLENCY, ROLLIN S. WOODRUFF, Governor of Connecticut, *Hartford, Connecticut.*

Sir: — I have the honor to transmit to you herewith, in behalf of the Connecticut Geological and Natural History Survey Commission, the report of the Superintendent of the work, covering the period of two years ending December 31, 1908.

Very respectfully,

FLAVEL S. LUTHER,

Secretary of the Commission.

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY

THIRD BIENNIAL REPORT

SCOPE AND PLAN OF THE SURVEY

There has been no change in the general scope and plan of the Survey since its first organization. It may, however, be convenient briefly to recapitulate what has been said thereon in former reports. The Survey was established by an act approved June 3, 1903. That act proposed for the Survey two subjects for investigation; viz., the geology of the state, and the natural history, or botany and zoölogy, of the state. It has been presumed to be the intent of the law that the appropriation should be divided with some approach to equality between geology and biology. The law establishing the Survey proposes definitely three aims with reference to which the work should be prosecuted: — first, the purely scientific aim of advancing our knowledge of the geology and natural history of the state; second, the economic aim of leading to the most effective conservation and utilization of the resources of the state; third, the educational aim of promoting the work of the schools of the state by the publication of the results of investigation in a form adapted for the use of teachers.

The plan of organization which was outlined in the first report has been retained. Only one salaried officer has been appointed by the Commissioners; viz., the Superintendent. Other scientific men have been engaged to investigate particular subjects and prepare reports or bulletins thereon. In the great majority of cases, the terms of contract with these scientific men have been that the investigator should receive a certain sum as compensation when the bulletin presented was accepted by the Superintendent, and that a certain allowance should also be made from the appropriation for the Survey for the expenses of the

work, the allotment for expenses to be drawn upon from time to time as the expenses were actually incurred. This allowance for expenses has been understood to be available for necessary travel, for the employment of stenographic or other clerical assistance, or for the employment of students or scientific men of less experience who could do some part of the work under the direction of the responsible investigator. In some cases, however, this form of contract has been impracticable, as investigations have been commenced and prosecuted in regard to which it could not be foreseen how soon they would result in conclusions definite enough for publication. In such cases the agreement has been to pay the investigator a small sum per diem, a maximum limit being prescribed in every such case.

Each report prepared is published as a separate bulletin, the bulletins being numbered consecutively, generally in the order of time in which they are received. Each bulletin bears the name of the author or the names of the authors, and each author is responsible for his own work. The bulletins are issued in paper covers, but a part of the edition is reserved for binding. Bulletins 1 to 5 have been bound as Vol. I. Bulletins 6 to 11 will be bound at an early date as Vol. II. The bound volumes are especially desirable for public libraries and similar institutions, in which complete sets of our publications are to be preserved. The pamphlet form, in which each bulletin is complete in itself, is convenient for the large number of students, teachers, and others who have use for some particular bulletin. The publications of the Survey are distributed by the State Librarian. They are given liberally to colleges, public libraries, geological surveys, and other scientific institutions, and to scientific men of repute in the branches of science with which the respective bulletins are concerned. In many cases publications of great value are received in exchange for the publications of the Survey. All books and papers thus received are deposited in the State Library. The publications of the Survey are also distributed liberally to citizens of our own state, particularly to teachers who can make use of them in their work. In the case of persons in other states who are not known as scientific men, and who appear to have no special claim for the donation of the publications of the Survey, the bulletins are sold at prices sufficient to cover the cost of printing and transportation.

BULLETINS ALREADY PUBLISHED

The two previous biennial reports of the Commissioners are numbered respectively in the series as 1 and 9.

Four bulletins on scientific subjects were published between the dates of publication of the first and the second biennial report. These were the following: —

No. 2. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut: by Herbert William Conn.

No. 3. A Preliminary Report on the Hymeniales of Connecticut: by Edward Albert White.

No. 4. The Clays and Clay Industries of Connecticut: by Gerald Francis Loughlin.

No. 5. The Ustilagineæ, or Smuts, of Connecticut: by George Perkins Clinton.

Five bulletins have been published since the presentation of the second biennial report. These are the following: —

No. 6. Manual of the Geology of Connecticut: by William North Rice, Professor of Geology in Wesleyan University, and Herbert Ernest Gregory, Professor of Geology in Yale University.

No. 7. Preliminary Geological Map of Connecticut: by Herbert Ernest Gregory, and Henry Hollister Robinson, Instructor in Geology in Yale University.

No. 8. Bibliography of Connecticut Geology: by Herbert Ernest Gregory.

No. 10. A Preliminary Report on the Algæ of the Fresh Waters of Connecticut: by Herbert William Conn, Professor of Biology in Wesleyan University, and Lucia Washburn (Hazen) Webster.

No. 11. The Bryophytes of Connecticut: by Alexander William Evans, Professor of Botany in Yale University, and George Elwood Nichols, Assistant in Botany in Yale University.

The Manual of Connecticut Geology is the first attempt at a somewhat detailed account of the geology of the entire state since the publication of Percival's report in 1842. It is needless to say that our knowledge of the subject has greatly advanced within the past sixty years. During that time much work has been done in the study of Connecticut geology by officers of the United States Geological Survey and by private individuals, and the general advance of geological science has put a new inter-

pretation upon many facts previously known. But the results of this work, so far as published, were scattered through many volumes of scientific serials and government reports, so as to be well nigh inaccessible to the majority of students and teachers. The publication of the Manual of Geology has accordingly supplied to the teachers and students of our state a long-felt need. The book consists of four chapters: — the first, by Professor Rice, on the physical geography of the state as related to geological structure; the second, by Professor Gregory, on the crystalline rocks; the third, by Professor Rice, on the Triassic sandstones and trap rocks; the fourth, by Professor Gregory, on glacial geology. The work is illustrated with 10 maps, 19 plates from photographs of scenery illustrating geological structure, and numerous diagrams. It has been heartily welcomed by the teachers of the state, who have in some cases purchased considerable numbers of copies for the use of their classes.

The Geological Map of Connecticut is on a scale of four miles to the inch. It has been produced in the best style of chromolithography by Julius Bien & Company. The map shows all the topography which is shown in the State Topographical Map on a scale of two miles to the inch, including the 100-foot contour lines. Roads are indicated by single lines. Notwithstanding the details of topography and culture which are represented on the map, the base map has been made sufficiently clear to show satisfactorily the geological coloring by the omission of all except a few of the most important names. The map has been issued in three different forms: — the first, printed on thin paper, to be folded and inserted in a pocket in the accompanying pamphlet; the second, printed on thick paper; the third, mounted on cloth for use as a wall map. The accompanying pamphlet, besides giving all necessary explanations for the understanding of the map, gives a brief history of geological investigation in the state.

The Bibliography of Connecticut Geology was prepared by Professor Gregory for his own use in investigation and teaching. It was recognized by the Superintendent of the Survey that such a work would be of great utility to all students and teachers of the geology of the state, and Professor Gregory generously gave his manuscript to the Survey without any compensation. It gives not only titles, but brief analyses of the contents, and

in some cases brief criticisms, of publications relating to Connecticut geology, whether appearing as independent works, or as articles in government reports or in periodicals. Mention is also made of maps showing the geology of the entire state or of parts of the state. The work will certainly be of great value to all students of Connecticut geology.

The Report on the Fresh-water Algæ, by Professor Conn and Mrs. Webster, is a companion work to Professor Conn's report on the fresh-water protozoa which was published as Bulletin No. 2. Together they constitute a partial fulfillment of the plan which was formed in the inception of the Survey, of making a thorough study of the microscopic life of our fresh waters. It was believed that such a study, apart from its scientific and educational value, might perhaps develop important results in reference to the reservoirs and other water supplies for drinking purposes. In the present report on the Algæ, analytical keys to genera and species are given, and the species which have been observed are represented in 45 plates, including 291 figures. Most of these figures are from drawings by Mrs. Webster. A few of them are by Professor Conn. They are exceedingly beautiful, and will be found very helpful by all students of this interesting group of organisms.

The report on the Bryophytes of Connecticut, by Professor Evans and Mr. Nichols, deals with a group of plants of great interest to the student of vegetable morphology and evolution, and not destitute of important economic relations, but a group which until recently has been almost entirely neglected by students and collectors of the plants of the state. The group includes the plants commonly known as mosses and liverworts. The present report is not illustrated; and is not intended to replace, but rather to supplement, the works which have been published, some of which are sufficiently accessible, on the systematic botany of the group. Analytical keys are given, affording a diagnosis of all the genera and species known to occur in the state. In connection with each species are given the names of all the towns in which the species have been observed and the names of the botanists by whom the specimens have been collected, together with the date of its first discovery in the state. The book affords thus a history of the study of a comparatively neglected group in the state. The special account of the Bryo-

phytes of Connecticut is preceded by chapters on the general characters of the class, the distribution of the species with reference to topography, climate, and geological structure, and the economic relations of the plants, and is followed by a very full bibliography.

BULLETINS ACCEPTED FOR PUBLICATION

The following bulletins have been accepted for publication: —

The Lithology of Connecticut: by Joseph Barrell, Professor of Geology in Yale University, and Gerald Francis Loughlin, Instructor in Geology in Massachusetts Institute of Technology.

The Flowering Plants and Pteridophytes of Connecticut: by a Committee of the Connecticut Botanical Society.

Second Report on the Hymeniales of Connecticut: by Edward Albert White, Assistant Professor of Floriculture in the Massachusetts Agricultural College.

The Triassic Fishes of Connecticut: by Charles Rochester Eastman, Curator of Vertebrate Paleontology in the Museum of Comparative Zoölogy, Harvard University.

The Insects of Connecticut, Parts 1 and 2: prepared under the direction of Wilton Everett Britton, Entomologist of the Connecticut Agricultural Experiment Station.

The bulletin on the Lithology of Connecticut contains a general introduction to lithology by Professor Barrell, and a special description of forty-one typical rocks from Connecticut localities by Dr. Loughlin. In the general part of the work, lithology is treated in relation to mineralogy and dynamical geology, so that the student may learn somewhat of the agencies by which the different types of rocks are produced, as well as their composition and characteristic aspect. Both in the general and the special part of the work attention is given chiefly to those characteristics of rocks which can be recognized by the naked eye or by the simple microscope, with comparatively little reference to the phenomena which can be observed only by the examination of thin sections under the compound polarizing microscope. This limitation of the discussion for the most part to characters observable by the naked eye renders the work adapted to the use of comparatively elementary students. The usefulness of the work in the high schools and other institutions in the state will

be greatly enhanced by the distribution to those institutions of suites of specimens of rocks from the typical localities described in the special part of the paper. These specimens were for the most part collected in the summers of 1905 and 1906. They will be distributed, as soon as the bulletin is published, to colleges, normal schools, high schools, and academies in the state, on condition that the institution shall pay the cost of transportation. Any suites of specimens remaining in the possession of the Survey after such distribution may be sold and the money paid into the treasury of the state.

The work of the Connecticut Botanical Society on the Flowering Plants and Pteridophytes of the state will be, particularly from an educational point of view, one of the most important bulletins of the Survey. The Connecticut Botanical Society, including a considerable number of enthusiastic botanists, professional and amateur, have been engaged for a considerable time in collecting material for a Flora of the State. Soon after the inception of the State Survey, the Connecticut Botanical Society acceded to the invitation of the Superintendent of the Survey, to furnish their work when completed for publication as a bulletin of the Survey. The Committee in charge of the work have given their services gratuitously, the Survey making only an allowance for necessary expenses. The bulletin gives a complete list of the plants known to occur in the State, arranged according to the classification adopted in the seventh edition of Gray's Manual of Botany, edited by Robinson and Fernald. In connection with each species, notes are given in regard to its geographical and topographical distribution. Special attention is naturally given to rare plants and to those plants the limit of whose range lies in or near our territory. Notice is also given of the economic relations of all plants which are in marked degree useful or injurious. In this work analytical keys and descriptions of genera and species are not given, since they can be found in Gray's Manual and other readily accessible books.

The Second Report on the Hymeniales, by Professor White, is chiefly occupied with a more detailed account of the family Agaricaceæ. This is the most important family of the Hymeniales, including a number of edible mushrooms and also some poisonous species. Besides giving a detailed account of this family, the paper will give a supplementary list of the species

of other families of Hymeniales which have been discovered in the state since the publication of the first report.

The bulletin on the Triássic Fishes, by Dr. Eastman, is a very important contribution to the paleontology of the state. The area of Connecticut is by no means rich in fossils. The crystalline rocks of the eastern and western highlands have proved as yet utterly barren of fossils. Whatever fossils some of these rocks may have once contained have been entirely obliterated by the processes of metamorphism. The Triassic formation of the Connecticut Valley has afforded scarcely any fossils, excepting tracks of reptiles and amphibians on some of the beds, and remains of fishes in two or three thin strata of black shale intercalated among the red sandstones. The scantiness of fossils in this formation has made difficult the determination of its geological age. Dr. Eastman has made a very careful study of all the important collections of the fossil fishes of this formation. He has been able thus to make a more exact determination of some features of the anatomy of the animals than has been made before. He has also made comparisons of the fish fauna of our Connecticut beds with the fish faunas of other Triassic formations in various parts of the world. This comparison leads him to the opinion that the age of our Connecticut formation corresponds most nearly, not with the uppermost European Trias (Keuper or Rhætic), but rather with a somewhat lower horizon, near the boundary between the Muschelkalk and the Keuper.

The bulletin on the Insects of Connecticut forms the beginning of a series of papers on that group of animals, whose publication may be distributed through a considerable number of years. It is needless to comment on the immense economic importance of the class of insects, many insects being the worst enemies of our agricultural interests, while others, insectivorous or parasitic in habit, tend to hold in check the destroyers of agricultural products. Two parts of the work have thus far been accepted for publication. Part 1 is a general outline of the character and relations of the class, by Dr. Britton, who is to act also as general editor of the whole series of papers on insects. Part 2 is a special discussion of the Orthoptera of Connecticut, by Benjamin Hovey Walden, Assistant in Entomology in Connecticut Agricultural Experiment Station. The mere mention of the words locust and grasshopper is enough to suggest the

importance of the economic relations of the orthoptera. These papers will be illustrated by a number of plates showing photographic representations of entire insects, and by drawings of diagnostic parts of the anatomy of the various groups.

WORK STILL IN PROGRESS

I. Geology

The geological investigations now in progress relate chiefly to surface geology, or the study of the phenomena connected with the work of the great ice sheet of the Glacial period. For more than a generation geologists have recognized that the mantle of heterogeneous and unstratified drift covering most of New England and the adjacent country is essentially the ground moraine of a continental glacier; that the widely scattered smooth, polished, and striated rock surfaces are the result of erosion by such a continental glacier; and that the stratified deposits in the river valleys consist of the débris transported by the glacier, sorted and redistributed by the action of water. But it is within a comparatively few years that a more thorough and detailed study has been given to these glacial phenomena. Of the comparatively small amount of study that has been given to the glacial geology of Connecticut, a considerable part has been vitiated by preconceptions now known to be erroneous, leading to false interpretations of observed facts, and preventing due appreciation of phenomena which might have been observed. There is need of a large amount of new study before the true history of the glacial and aqueo-glacial formations of the state can be determined.

Dr. F. P. Gulliver of Norwich has been at work for some time on a detailed study of the terraces bordering the estuary of the Thames. These shelves of stratified sand and gravel at a considerable elevation above the present level of the river have been supposed to be remnants of a great sand and gravel plain which was once substantially continuous across the valley, and which was formed, after the retreat of the ice from the portion of the valley in question, by deposition in the waters of the river, whose velocity was at that time feeble by reason of diminished slope and excessive load of sediment. A number of years

ago Dr. Gulliver published a preliminary paper on the terraces of the Thames, in which he gave reasons for the belief that those terraces were formed on the edges of the valley while a tongue of ice still lingered in the central part. Various students have shown reasons for a similar belief as regards the terraces in the lower or estuarine portions of other rivers of the North Atlantic slope. The study of these terraces is therefore of great interest in the endeavor to trace out the detailed history of the later stages of the ice age. Dr. Gulliver has accordingly undertaken to make a more detailed survey of the terraces of the Thames River, and to furnish the result for publication as a bulletin of the State Survey.

Numerous other problems present themselves in the detailed study of the glacial geology of this region. Studies of the glacial formations in the Mississippi Valley, in northern Europe, and in the Alpine region, have clearly revealed the fact that the Glacial period was more complex than was formerly supposed. There were repeated alternations of rigor and mildness in the climate, in accordance with which the great ice sheets alternately advanced and retreated. The deposits of earlier ice sheets can be recognized in some regions, emerging from beneath the edge of the later deposits, while in some localities stratified and fossiliferous interglacial deposits can be recognized between the older and the younger glacial formations. In New England the latest advance of the ice sheet extended beyond the shore line, and it has been generally supposed that the latest ice invasion so thoroughly disturbed all deposits of the earlier ice sheets, as to leave no recognizable remains of them. There is need, however, of thorough study of precisely this question. There is need also of careful examination for the purpose of tracing in more detail the history of successive stages in the final recession of the ice sheet. During the summer of 1907 Professor H. E. Gregory devoted considerable time to field work in the study of the Glacial formations of the state. As a preliminary result of this study, a bulletin on the Glacial phenomena of the Naugatuck Valley will be ready at an early date. In the Geological Map of Connecticut, which was published as Bulletin No. 7, surface geology was entirely ignored, the map representing only the bed rocks which lie beneath the mantle of drift. It is expected that Professor Gregory's work

will result eventually in the preparation of another general map of the state showing the surface geology, and a volume of text tracing with some approach to completeness the history of the Glacial period in our state.

The melting away of the great ice sheet left the surface of Connecticut and of the adjacent country dotted with innumerable lakes and ponds, many of which have already become obliterated. One of the processes which have led to the disappearance of these ponds is the accumulation of the débris of vegetation, converting the ponds into peat bogs. The peat is not only of great scientific interest, both to the geologist and to the botanist, but possesses considerable economic importance, having uses as a fuel and as a fertilizer, and being capable also incidentally of employment for various other purposes. Attention has recently been called to the economic value of peat by the investigations of the United States Geological Survey, which have shown its special fitness for use in the gas-producer. It was, therefore, deemed desirable to make a special investigation of the peat deposits of Connecticut, and this was rendered practicable by the generous coöperation of the United States Geological Survey. During the summer of 1907 the field work of the investigation was substantially accomplished. The localities of all the important peat bogs of the state were visited, the area of those bogs was noted, their depth was determined by a sounding apparatus, and samples for analysis were collected from various depths. This work was accomplished by Messrs. E. C. Miller, A.B., and T. T. Giffen, A.B., of Yale University. Professor C. A. Davis of the University of Michigan, who was employed by the United States Geological Survey in the summer of 1907 for a reconnoissance of the peat deposits of the Atlantic border of the country from Maine to Florida, was permitted by the courtesy of the United States Geological Survey to spend a few days in Connecticut at the beginning of the season of field work. He was able, therefore, to give Messrs. Miller and Giffen the necessary instruction in regard to methods of work. The bulletin which will be published will contain a general paper on the scientific and economic relations of peat, by Professor Davis, who has made himself eminently an authority on the subject. It will also contain the notes of Messrs. Miller and Giffen in regard to their field work. A selection of samples collected by Messrs. Miller and Giffen have been analyzed in the laboratory of the United States Geological Survey, and reports of those analyses will be

included in the bulletin. The State Survey is very greatly indebted to the liberality of the United States Geological Survey for the all-important assistance of Professor Davis at the beginning of the investigation, and for the analyses made in the laboratory of the United States Geological Survey.

II. Botany

Dr. G. P. Clinton of the Connecticut Agricultural Experiment Station, whose paper on the smuts was published as Bulletin No. 5, is at work on another important group of parasitic fungi, viz., the downy mildews. This group includes a number of parasites destructive to important agricultural products, and the bulletin will be therefore an important contribution to the economic botany of the State.

Professor Conn, whose work on the protozoa and algæ of the fresh waters of Connecticut has been published as Bulletins 2 and 10, is continuing his study of the microscopic life of the fresh waters by an investigation of the bacteria. The relation of bacteria to public health is so well understood as to make it obvious that a study of the distribution of bacteria in the reservoirs and other sources of drinking water must be of great importance from a practical as well as from a purely scientific point of view. A preliminary report on the bacteria will be presented at an early date.

III. Zoölogy

Mr. John H. Sage of Portland and Dr. Louis B. Bishop of New Haven are still at work upon their bulletin on the birds of Connecticut. It will contain a vast amount of information in regard to the dates of arrival and departure of our migratory birds, the localities of rare birds, and the food and habits of the birds. This bulletin will be of interest not only to ornithologists but also to teachers and farmers. It will tend to correct some erroneous impressions which are prevalent in regard to the relation of some birds to agricultural interests. Some of the birds of prey, for instance, which are commonly regarded as the farmer's foes, are really the farmer's friends. In fact, the sharp-shinned hawk, Cooper's hawk, and the great horned owl are probably the only birds of prey that are in any considerable degree injurious to agriculture in Connecticut.

As stated above, two parts of a work on the insects of Con-

necticut, prepared under the direction of W. E. Britton, have been already accepted for publication. Part third, relating to the hymenoptera, is nearly completed. This part is by Mr. Henry L. Viereck, formerly of the Connecticut Agricultural Experiment Station. The hymenoptera, including the bees, wasps, ants, and saw-flies, are a group of great interest from an economic as well as from a purely scientific point of view, many of them being eminently useful and others decidedly injurious to agriculture.

A bulletin on the echinodermata of Connecticut, by Professor W. R. Coe of Yale University, is nearly ready. The starfishes, which are among the best-known representatives of this group, occasion a very serious loss to the resources of the state by the ravages which they make in oyster beds. Professor Coe has given much attention in this bulletin to the economic relations of the group. The paper will be beautifully illustrated, and will be of much use to the teachers of natural history in the schools.

DISTRIBUTION OF THE APPROPRIATIONS

The expenditures for work which has been completed and for which full payment has been made since the last biennial report have been as follows: —

Name	Work	Compensation	Expenses
W. N. Rice	Superintendence, 1905-7	$400	$256.49
H. W. Conn	Fresh-water Algæ	150	250.00
A. W. Evans and G. E. Nichols	Bryophytes	100	50.00
J. Barrell and G. F. Loughlin	Lithology	150	550.00*

The allotments for work which is still in progress, or for which full payment has not been made, are as follows: —

Name	Work	Compensation	Expenses
W. N. Rice	Superintendence, 1907-9	$400	$300
F. P. Gulliver	Thames River Terraces	171	154
H. E. Gregory	Quaternary Geology	900†	
C. R. Eastman	Triassic Fishes	300	100
C. A. Davis, T. T. Giffen, and E. C. Miller	Peat	329	320

* The exceptionally large allowance for expenses provided for the collection of suites of specimens for distribution.

† This investigation requires a very large amount of field work.

Name	Work	Compensation	Expenses
Conn. Botanical Society	Flowering Plants and Pteridophytes		300
G. P. Clinton	Downy Mildews	50	25
E. A. White	Fungi	100	75
H. W. Conn	Fresh-water Bacteria	200	250
J. H. Sage and L. B. Bishop	Birds	200	200
W. R. Coe	Echinoderms	75	25
W. E. Britton	Insects	125	125

The smallness of the compensation, in comparison with the grade of ability of the workers, the amount of the work, and the value of the results, is very noticeable.

PLANS FOR FUTURE WORK

I. Geology

It may be said in general that there is need of more detailed study in most parts of the state than has yet been accomplished. Apart from the problems of surface geology, the area of the state most thoroughly studied is that of the Triassic formation. The area where detailed work is most lacking as yet is that of the eastern crystallines. The geological work which has been done in much of eastern Connecticut amounts to little more than a reconnoissance. The Manual of Geology, and the Geological Map by which it is supplemented, bear most eminently the character not of final reports, but of reports of progress. Their publication was amply justified by the need, on the part of teachers and others, for publications which would set forth in convenient and intelligible form our present knowledge of the geology of the state. But they certainly will require very much of correction in detail. It is, moreover, not unlikely that more detailed study will bring to light facts which will lead to very important changes in the general conception of the geological history which is recorded in our rocks.

The necessity for more detailed study in various parts of the state is even greater in regard to surface geology than in regard to the geology of the underlying rocks. Professor Gregory has made a beginning of such investigation; but a vast amount of careful work must be done before we can reach the true history of the Quaternary era in our territory.

A report on the mineralogy of our state would be very useful. Lists of American localities of minerals have been published in

a number of editions of the works of J. D. and E. S. Dana on mineralogy, the latest being in the sixth edition of the System of Mineralogy, published in 1892. A list of Connecticut minerals by Hattie E. Cochrane, dated 1894, is contained in the Report of the State Board of Education for 1896. Neither of these lists is by any means complete. Moreover, a report of the mineralogy of the state should be much more than a mere list of minerals occurring in the respective towns. Such a report should give more detailed information in regard to localities of interesting and important minerals, and should enter into some discussion of the geological relations of the minerals.

Among the bulletins already accepted for publication, is one on the Triassic fishes by Dr. Eastman. Besides these fishes, the Triassic rocks afford another interesting class of fossils; namely, the tracks of various animals, chiefly reptiles and amphibians. A future bulletin should be devoted to a revision of these tracks.

In the introductory chapter of the Manual of Connecticut Geology is found a brief discussion of the physical geography of the state in relation to geological structure. A subject whose treatment in a bulletin or in a series of bulletins would be of great educational value, would be the physical geography of various parts of the state, particularly in relation to human life and history. In such publications the influence of geographic conditions in the location of towns, in the determination of routes of travel, and in the control of the industries of the state, should be discussed. Such bulletin or bulletins on the physical geography of the state would be of great interest to all intelligent citizens, and particularly to the teachers in our schools.

II. Botany

The labors of the Connecticut Botanical Society have given to us a list of the flowering plants of the state, and of the ferns and their allies. This paper will afford much information in regard to the geographical and topographical distribution of particular species of plants. An appropriate line of investigation, and one in regard to which it may be hoped that the Survey may be able to publish important papers in the future, would be the more extended study of the distribution of plants with reference to altitude, geological formation, distance from the sea, temperature, and rainfall, and the grouping of plants into plant societies

be ready also to give attention to particular investigations which may have a special importance, for economic or other reasons, at some particular time. Moreover, the work of a Geological and Natural History Survey can be carried on much more economically by the plan of small appropriations maintaining a permanent organization, than by the plan of attempting to complete the work in a few years and then doing it over again a generation later. The experience of our Connecticut Survey illustrates well the economy of this method of procedure. Field work can be done in the summer vacations by college professors, teachers, and others who are willing to do a certain amount of such work for very small compensation. Investigations can be made and bulletins can be written in large degree in odds and ends of time, by men who receive salaries for work in the colleges and other institutions of learning, or in museums and other scientific institutions. Under such conditions men of a high grade of ability and attainment are willing to offer for publication the result of their investigations for merely nominal compensation. The amount of valuable material already published, and the amount which is ready or nearly ready for publication, by our Survey, in comparison with the very small cost, is a striking illustration of the economy of this method of procedure. If, on the other hand, the work of a Survey is to be completed, and final reports presented in a few years, it is generally necessary that a number of competent men should be employed to give practically their whole time to the work. They must be paid salaries which will justify them in resigning any official positions which they may hold and taking their chances of securing other employment when the work of the Survey is finished.

If the State Geological and Natural History Survey is recognized as a permanent institution, it is not important that its annual appropriation should be largely increased. Our annual appropriation is certainly one of the smallest, if not absolutely the smallest annual appropriation afforded at the present time by any state which maintains a Geological or Natural History Survey. Several of the states have been making, year after year, an appropriation of $10,000 for geology alone, in comparison with which our appropriation of $1,500 a year for geology, botany, and zoölogy seems pretty small. In the states referred to, this large appropriation for geological work is exclusive of

the cost of publication, as is the case with our own appropriation. If, in its wisdom, the General Assembly is disposed slightly to increase the appropriation for the State Survey, we will undertake to make good use of the additional money; but we are not disposed strenuously to urge an increased appropriation. If the Survey can be recognized as a permanent institution and the same annual appropriation can be assured, and if adequate provision can be made for the publication of the results of the Survey, the conditions for the work of some years in the immediate future will be satisfactory.

LEGISLATION DESIRED IN REGARD TO PUBLICATION OF BULLETINS

The law establishing the Survey made it the duty of the Commissioners to cause to be prepared a report to the General Assembly before each meeting of the same, and special reports, with necessary illustrations and maps, on the geology and natural history of the state. It also made it the duty of the Commissioners to direct in regard to the sale or distribution of the reports, when printed. It imposed upon the Commissioners no responsibility for the printing. It was the obvious intent of the act that the whole of the small appropriation made for the Survey should be devoted to the scientific work of investigation and preparation of the reports. The cost of publication of the reports was to come out of the general funds in the treasury of the state. When the first bulletin of the Survey came to be printed, an unexpected difficulty appeared. The general law in regard to the state printing provides for the printing of not more than 1,575 copies of any official report. But such an edition is utterly inadequate for the bulletins in the Survey. It is desired that these bulletins should be, as is customary in the case of similar publications in other states, widely distributed to colleges, scientific institutions, public libraries, scientific men, teachers, and others. The editions of similar reports published by other states generally range from 3,000 to 8,000. It is obviously useless to prepare elaborate scientific reports, and then print so small an edition as to render it impossible for those reports to reach the persons who would desire to use them. Hence the necessity for some action of the General Assembly to provide for the printing of the bulletins of the Survey.

At the session of the General Assembly in 1905, the matter

was dealt with for the time being by a resolution authorizing the printing of the desired numbers of copies of certain specified bulletins, and of such others, not exceeding thirteen in number, as might be ready for printing before January 1, 1907. Under this authorization Bulletins 1 to 9 were printed.

At the session of 1907, the General Assembly adopted a resolution authorizing the Comptroller "to have printed, in lieu of the number of copies authorized by the general statutes relating to public documents, 3,000 copies of the regular and special reports of the State Geological and Natural History Survey, and, in addition to the number hereinbefore specified, such number of any of the special reports of said Survey as may be requested by the Commissioners of said Survey and approved by the Board of Control; provided, that the total number of copies of any report so printed shall in no case exceed 4,500." The second section of the resolution appropriated the sum of $5,000, for the two fiscal years ending September 30, 1909, "in full compensation for the purposes of this resolution." There has been some doubt in regard to the intent of the second section. Was that $5,000 appropriated to cover the entire expense of the publication of all bulletins which should be printed prior to September 30, 1909? or was that $5,000 appropriated to provide for the printing of the numbers of copies in excess of the number of copies of public documents authorized by the general law? No legislation was needed to authorize the printing of 1,575 copies of each of the reports, since that was made the duty of the Comptroller by the original act. Special legislation was required only to authorize the printing of the number of copies called for in excess of the number specified in the general law. The Board of Control, doubtless wisely, adopted the more conservative construction of the resolution, holding that the $5,000 appropriated in the second section of that resolution must cover the entire cost of publication of bulletins of the Survey which should be printed prior to September 30, 1909. Bulletins 10 and 11 have been printed; and the Board of Control has authorized the printing of the bulletin by Professor Barrell and Dr. Loughlin on the Lithology of Connecticut, and the bulletin of the Connecticut Botanical Society on Flowering Plants and Pteridophytes of Connecticut. But these bulletins will so nearly exhaust the $5,000 appropriated that no other bulletins can be printed until some additional action is taken by the General Assembly. Several bulletins containing

the results of important investigations have been accepted for publication, but must remain unpublished until some action is taken by the General Assembly. The bulletins whose publication is thus deferred are the following: Second Report on the Hymeniales, by Professor E. A. White; The Triassic Fishes of Connecticut, by Dr. C. R. Eastman; and Parts I. and II. of the work on the Insects of Connecticut, prepared under the direction of W. E. Britton. A number of other bulletins are nearly ready, and will doubtless be presented to the Superintendent within the next few months. It is certainly to be greatly regretted that the publication of these valuable bulletins should be delayed by the lack of authorization to print them.

In the resolution passed by the General Assembly in 1907, it was assumed that the minimum number of copies of any bulletin would be 3,000, and that a larger number of copies would be required for some of the bulletins. From what has already been said in regard to the bulletins which have been accepted for publication, or which are in an advanced stage of preparation, it will be obvious that some of them are of a more popular character than others, and will appeal to a wider constituency of readers. The respective numbers of copies deemed necessary to meet the demand which may be reasonably anticipated in the case of the bulletins already accepted for publication but not yet ordered by the Board of Control to be printed, and of those bulletins which are approaching completion and which may be expected to be ready for publication within a few months, are shown in the following table: —

Author	Subject	No. of Copies
F. P. Gulliver	Thames River Terraces	3000
H. E. Gregory	Quaternary Geology of Naugatuck Valley	3500
C. R. Eastman	Triassic Fishes	3500
C. A. Davis and others	Peat	4000
G. P. Clinton	Downy Mildews	3000
E. A. White	Fungi	3500
H. W. Conn	Fresh-water Bacteria	3500
J. H. Sage and L. B. Bishop	Birds	4500
W. R. Coe	Echinoderms	3500
W. E. Britton	Insects	3500

We accordingly earnestly petition the General Assembly either specifically to authorize the printing of the number of copies above specified in the case of each of the forthcoming bulletins, or to pass a resolution authorizing the printing of such editions of the respective bulletins, not exceeding 4,500 in any case, as may be recommended by the Board of Commissioners and approved by the Board of Control.

Attention has already been called to the large amount of valuable scientific work which the Survey has produced at very small cost. Scientific men in our own state, and even outside of our state, have been willing to contribute to the Survey bulletins containing the result of years of study, for merely nominal compensation. The work of the scientific men in the Survey has been truly a labor of love. But the printers cannot be expected to work for love. They must be paid. And we earnestly appeal to the General Assembly for generous action in regard to the publication of the bulletins of the Survey, that the labors of the scientific workers may not be rendered useless by failure to authorize their publication.

THE TOPOGRAPHICAL ATLAS OF CONNECTICUT

In addition to the regular work of the Survey, the last General Assembly imposed one special duty upon the Commissioners of the State Geological and Natural History Survey. The supply of bound copies of the Topographical Atlas of the state, in the office of the State Librarian, is now nearly exhausted. There is a steady demand on the part of citizens of the state for the purchase of bound copies of the atlas, as well as for the purchase of separate topographic sheets. On recommendation of the State Librarian, the General Assembly at its last session instructed the Commissioners of the State Survey to procure from the Director of the United States Geological Survey 500 copies of the sheets of the Topographical Atlas of Connecticut, and to cause the same to be suitably bound. A subsequent section of the resolution appropriated the sum of $1,000 for this specific purpose.

At the time this resolution was passed it was hoped that some revision might be made in the sheets to be purchased from the United States Geological Survey. There are some inaccuracies and a few glaring errors in those topographic sheets as originally

published. Since the publication of those maps there have been some changes in the lay-out of railroads and highways in different parts of the state, and some changes in town boundaries. The inter-urban electric railways have come to be a very important feature in the life of the state. It was hoped that we might be able to secure from the United States Geological Survey a more or less thorough revision of the plates before the printing of the 500 copies which it was proposed to purchase.

It appeared, however, on correspondence with the Director of the United States Geological Survey that such revision would be impracticable. The state of the case is set forth in the following extract from the letter of George Otis Smith, Ph.D., Director of the United States Geological Survey: —

"The whole proposition would be altogether desirable, provided we had the means with which to carry it out. There is need of some legislation whereby the Engraving Division of the Survey may furnish any State Survey with reprints of our maps in whatever form desired, at actual cost; but under the present statute, while such outside work is permissible, it is not practicable, inasmuch as all work of this kind reduces just so much the new work of engraving and printing. When over 60 per cent. of the area of the United States is without any topographic map, I hesitate to expend much money in bringing up to date the sheets earlier issued by the Survey. I think you will not fail to appreciate my feeling that additional work in Connecticut, which has been completely mapped, must take second place to mapping work in Mississippi, of which only 2 per cent. has been covered."

It appears, accordingly, that any revision of the topographic sheets is out of the question until some new legislation on the part of Congress may make it possible for a revision of the old topographic maps to be made by some form of coöperation between the national and the state authorities. In the meanwhile, it appears that there remains at present in the office of the State Librarian a small supply of unbound copies of the topographical sheets of the special uniform edition printed for the state in 1893. It seems therefore the wisest plan simply to bind up 250 copies of the sheets now on hand. This number of bound atlases will meet any demand which may reasonably be expected for the next few years. In case the supply of any particular sheet in the office of

the State Librarian should be exhausted, additional copies can from time to time be obtained from the Director of the United States Geological Survey, under the ordinary terms of sale, without any special arrangement. Such copies will not be quite uniform in style with the state edition, but for purchasers of separate sheets the lack of uniformity will not be objectionable.

The binding of 250 copies of the sheets now on hand will, of course, require the expenditure of only a small part of the $1,000 appropriated for the purpose of the topographic atlas, and the remainder of the amount can be returned into the treasury of the state.

General Index to Volume II.

Numbers of bulletins are Roman numerals; numbers of pages Arabic. Bulletin numbers without page numbers are given for authors and subjects of bulletins.

1 sheet